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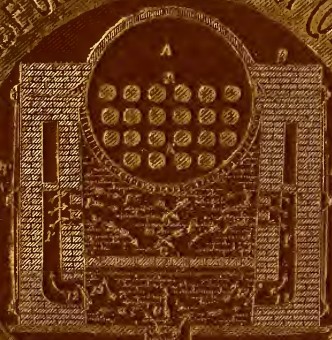
Triumph of Combustion

A Treatise on the Science of Combustion. A New System to Complete Combustion.



National Electric Furnace.

1887.

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UNITED STATES OF AMERICA.

Triumph of Combustion.

A TREATISE ON

The Science of Combustion

INTRODUCING

A NEW SYSTEM TO COMPLETE COMBUSTION.

ALSO A COMPENDIUM OF

MISCELLANEOUS VALUABLE INFORMATION.

DEVOTED TO

MANUFACTURERS, STEAM-USERS, ENGINEERS, MECHANICS, ETC.

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PUBLISHED BY THE

NATIONAL ELECTRIC FURNACE CO.

ST. LOUIS, MO.

1887.

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PREFACE.

This little volume, introducing a new system of combustion, will be found to embrace a number of instructive truths pertaining to the science of combustion. These truths have been collated from many reliable sources with great care. The writer having for over twenty-five years had theoretical and practical experience as a steam user and engineer, deemed the information herein contained valuable enough to be presented to others interested in the same subject, who, although in proper state for receiving these truths, remain in total ignorance of their existence, and have no means of knowing them except through some such effort as this. For the benefit of all such, certainly not for the writer's own emolument except so far as happiness may be derived from the consciousness of having tried to be of use to others, the following pages have been transmitted to publication.

St. Louis, November, 1886.

GEO. HASECOSTER.

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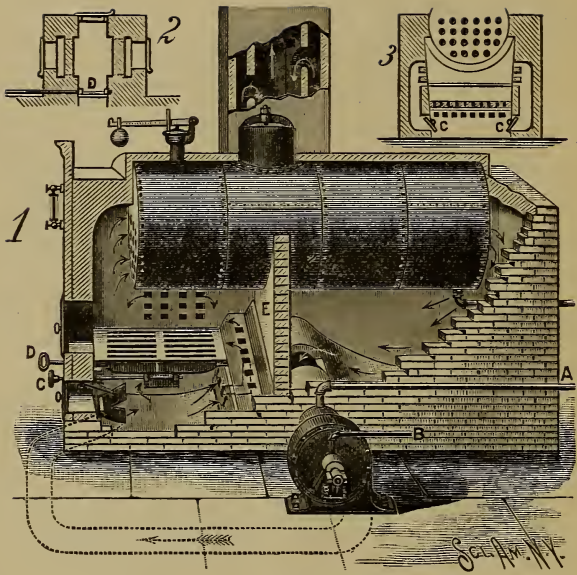


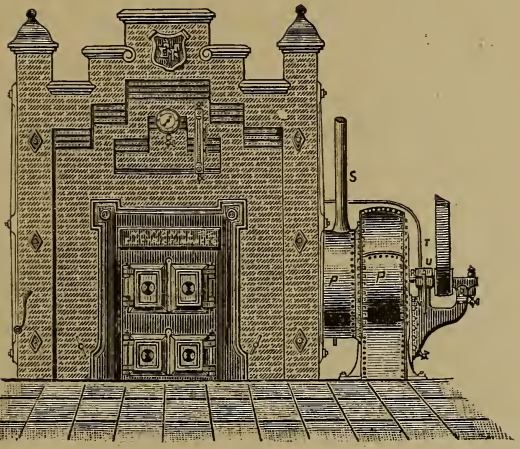
National Electric Furnace.

The object of the improvement herewith illustrated is to provide a furnace for steam boilers of any *approved construction*, in which furnace a complete combustion of the fuel is accomplished by introducing a mixture of steam, (exhaust steam), hot air, and gases into the fuel. The above engraving represents a fire tube, or flue boiler, mounted in brickwork. This furnace takes the combustible gases from the hot air chamber, and, after adding steam and air, forces them into the combustion chamber, where they not only serve to support combustion, but themselves constitute a new fuel (water gas). By these means the great waste of fuel can be avoided, and a greater volume of water evaporated with less fuel.

For further information address

NATIONAL ELECTRIC FURNACE CO., ST. LOUIS.

Artificially Forced Combustion.



Introduction.

The Science of combustion and the enormous waste of fuel, in small fires, as in domestic operations, in stoves, and furnaces, while imperfectly understood even by most men of science, is scarcely thought of by the great mass of people. This little volume will enable those, who are entirely unacquainted with the science of combustion to understand the same and the elements that take part in it.

It will give answers to the following questions. What is coal?—What is fire?—What is flame?—What is heat?—What is carbon?—What is the composition of air?—What is oxygen?—What is hydrogen?—What is gas which escapes from the coal?—What is nitrogen?—What is smoke?—What is water?—What is steam?—

It will show that the nature of combustion is nothing more than an energetic chemical combination, or, in other words, that it is the mutual neutralization of opposing electricities, as will hereinafter be explained. It will also serve to introduce a new system of combustion in furnaces for steam boilers and for other purposes.

G. H.

The Science of Combustion.

The science of combustion is in itself simple, but to those who are entirely unacquainted with it, it appears mysterious. Since, however, there are a great many, to whom this science really is a mystery, we have deemed it necessary to premise this small treatise in order to enable a better understanding of the advantages of the "National Electric Furnace." This treatise has been adapted from the second part of a work, entitled "Library of Popular Sciences," by one A. Bernstein, a German writer on natural science. The work named was published by Chr. Schmidt of New York, and the passage referred to reads mainly as follows:

"Chemical elementary substances have a peculiar tendency to unite, and this tendency is strongest between substances that are naturally most dissimilar. But we must not suppose that two substances will always unite immediately on being brought into contact, for certain circumstances must generally meet in order to effect, support, and hasten the uniting.

Oxygen and coal united form carbonic acid, but in order to effect the union of oxygen and coal the latter must be ignited, that is to say, the union of oxygen and coal is effected by the application of a certain degree of heat to the latter. This is also

the case with other substances. Sulphur may be left in oxygen for days without uniting with it, but as soon as a small portion of the former is ignited, the union will be effected and produce such heat as will be needed to ignite the rest of the sulphur and thus make the union progress.

It is quite important to explain this as clearly as possible, for it will enable us to understand a great many phenomena which are daily taking place before our eyes.

How is it that wood when brought into contact with live coal, will ignite and change into coal? The reason is that live coal impart to wood a high degree of heat, when brought into contact with it. Since wood itself, however, consists to a great extent of carbon, the heat from the live coal causes the carbon of the wood to unite with the oxygen of the air, and thus the particles of wood in direct contact with the live coal are ignited. Fresh air is therefore absolutely necessary for the progress of the union, since it can only continue as long as it is supplied with fresh oxygen. The supply of oxygen being cut off, the chemical union of oxygen and carbon will cease, the fire will go out.

Every child, therefore, already knows that fire in a stove in order to burn well must have a good draught; the hot air having been robbed of its oxygen, must leave the stove by way of the flue above, and fresh air containing oxygen, must enter the stove from below, so that the oxygen may continually unite with the heated coal and the fire burn on. Indeed, no fresh air, and hence no new oxygen being allowed to enter the stove, the fire will go out, for fire only originates through the oxygen of the air entering into a state of chemical union with the carbon of the wood. If an apparatus could be con-

structed to create fresh oxygen within the stove, this would do away with the draught; for, while there is oxygen within the stove, the fire will burn, or, in the language of chemists, the chemical union of oxygen and carbon will take place.

Hence it is quite natural that fires burn best in stoves with a good draught—that is to say, stoves, through which a strong current of air is continually passing—because a large quantity of oxygen passes from the air into the heated fuel and unites with it chemically. We also blow into a fire to make it burn brighter, that is, by blowing we drive a greater volume of air into the fire and thereby bring more oxygen into contact with the heated wood. The blacksmith makes use of his bellows to force a great volume of air into the fuel and thereby causes a rapid and energetical chemical union of oxygen and carbon resulting in fire, since fire itself is but a phenomenon occurring whenever oxygen is rapidly and energetically united with carbon or other substances.

So we find it to be quite true what chemistry teaches about combustion, viz., *that combustion is nothing but a chemical process, and that fire is only the phenomenon resulting from such process*, and we also find that chemistry is practised unconsciously by almost everybody, for as often as we light a lamp or kindle a fire, we do but effect a state or condition in which certain substances may unite with the oxygen of the air.

A light will be extinguished by being deprived of the oxygen of the air. Place a small end of a taper on the table, light it, and cover it with a tumbler. You will soon see the flame grow darker, until finally the light will go out. Why is this? The oxygen contained within the tumbler has been consumed, and hence the chemical union, called com-

bustion, ceases. So you see, that combustion can only continue while the combustible is uniting with the oxygen of the air. If means could be found to extract the oxygen from large volumes of air, we should be able to extinguish the largest conflagration in an instant simply by depriving the fire of the oxygen.

The flame of a common light also may teach us a great deal. The edge of the flame, coming closely into contact with the oxygen of the air, is hot and bright, while the centre, coming very little into contact with the oxygen, is neither as bright nor as hot. Hold a chip of wood directly into the flame, and you will notice, that the chip will not catch fire first in the centre of the flame, but on the edges. With a little dexterity the chip can be taken out, before it catches fire, and then you will notice that only the edges of the flame have charred it, while the centre of the flame hardly singed it.

This teaches us that the faster and readier a combustible unites with oxygen, the greater a degree of heat will be originated, and the slower and more reluctant a substance unites with oxygen, the lower a degree of heat will be originated.—And now we can also easily understand why it is, that stoves, in which the fuel is consumed slowly, will radiate less heat, while stoves, in which the fuel is consumed more rapidly, will also radiate more heat. The former have not sufficient draught, the quantity of oxygen coming into contact with the fuel is therefore not sufficient and so the flame not hot enough. In stoves with a good draught, the quantity of oxygen coming into contact with the fuel is sufficient, the flame is hotter, heats the stove more rapidly and to a higher degree, so that the stove radiates more heat.

It is also quite important that a sufficient quan-

tity of oxygen be admitted to the flame for the reason that it will cause a great many particles of the fuel to be consumed, which would otherwise pass away unconsumed. Every cook knows that, whenever the fire in the range will not burn, a great volume of smoke is formed, but after having been blown into, the flame will leap up and the smoke disappear. Smoke, however, is hardly anything else but fine carbon, which rises with the hot air from the fire. By blowing into the fire, we know, a greater quantity of oxygen is imparted to it, and its heat is increased to such an extent, that the fine particles of carbon contained in the smoke will unite with the oxygen and give a beautiful hot flame. By withdrawing the oxygen, however, the fine particles of carbon in the smoke and, therefore, a valuable part of the fuel, pass on, partly settling in the chimney, partly flying out into the open air and settling on surrounding surfaces in the form of soot. —A common coal-oil lamp will afford an excellent experiment to prove this. Take off the chimney, and the light will flicker, form smoke, and grow dim; put the chimney on again, and the light will instantly burn with a bright, pure, and white flame. How can this be accounted for? Why, the chimney being open above and below, causes a strong current of air. The hot air constantly leaves by the opening above, and fresh air as continually enters from below. This current of air constantly supplies the flame with oxygen, and thus a sufficient degree of heat is originated to consume even the soot. As soon, however, as the chimney is taken off, the current of air ceases, the quantity of oxygen supplied by the surrounding air is insufficient for a good combustion, and so a part of the combustible is lost in the form of soot.

Since combustion is nothing but a chemical union effected chiefly between carbon and oxygen, and fire is but a phenomenon attending this union, what may be the product of this union, or what originates from it? The product of this union is chiefly carbonic acid, a substance also occurring free as a gas in the atmosphere, to the extent of 1 volume to 2500 of air, and also in combination with a variety of substances. It is often called fixed air or choke damp, and being poisonous can not be inhaled without danger, as it not only furnishes no oxygen for purifying the blood, but it adds additional poison to it. As combustion can not be produced in common air without consuming oxygen, and giving out in its place carbonic acid, an open fire in a close room must render the air impure. If a lighted taper be placed in a closed jar containing common air, the oxygen will soon be burned up, its place will be supplied with carbonic acid and vapor, and the light of the taper will be extinguished. If a living animal, a mouse, for example, be now placed in the jar, and especially at the lower part of it, the animal will almost immediately go into convulsions, and die in two or three minutes.

As pure charcoal consists almost entirely of carbon, the burning of charcoal produces a large quantity of carbonic acid; and every year cases occur of individuals having lost their lives by entering close rooms in which charcoal was burning. As this gas is much heavier than common air, it may occupy the lower portion of a room near the floor, while the air above may be nearly free from its influence. Persons have also lost their lives by descending into deep pits, wells, and mines, which contained carbonic acid. Before venturing into such places the precaution should be used of let-

ting down a lighted candle; if the light be extinguished, or burn feebly, carbonic acid may be known to exist there. When discovered it may often be absorbed by quick lime, if it can not be drawn off or dissipated by ventilation.

We have adduced these remarks on carbonic acid in order to show that really every stove is a chemical factory producing carbonic acid, and because we think it most important that everybody should be instructed in regard to the dangers of the same, too many sad results constantly occurring from ignorance or disregard of them. For this purpose, we also add, that in dubious cases, whenever the presence of carbonic acid in a room is but supposed, we must not judge according to the higher strata of air in the room, but explore the lower in order to insure against accidents.

In speaking of the elementary substances taking part in combustion we have hitherto mentioned two, oxygen and carbon, the former of which is supplied by atmospheric air, while the latter exists in the fuel. But fuel, especially coal, the fuel most in use, does not consist of pure carbon alone, but also contains hydrogen, and, therefore, we can not afford to pass this substance by unnoticed. This substance, which is also a gas, may seem to be unknown to most people, but in reality everybody is well acquainted with it, since it strikes our eyes hundreds of times in a single day. The gas of the lamps in our streets consists chiefly of hydrogen mixed with a little carbon. The burner of a gaspipe being opened, a gas or air will stream forth, which is invisible to the eye, but as soon as a lighted match is held above the burner, the air or gas around the match will ignite, and the flame will go downward to the opening of the burner and proceed to burn there, while

the gas streams forth. If the lighted match be held a little distance above the burner, the flame will seem to drop from the match to the burner, but a little reflection will readily bring us to the conclusion that this is a misconception.

We have presented this example of common gas in order to show that hydrogen is really not a kind of matter entirely unknown to us. Common gas, however, does not consist of pure hydrogen alone, and we will, therefore, seek to become acquainted with the latter.

Hydrogen, so called from the Greek word *hydor*, water, forms two thirds of the bulk of water. For all the water of wells, rivers, lakes, and seas is not an elementary substance, but consists of two kinds of gases chemically united, one being hydrogen and the other oxygen, both of which can be produced out of water. Indeed, if ever means should be found, which would enable man to produce both of these gases out of water at a small expense, humanity would have taken a great step forward, for we should then be able to procure the fuel for kitchen, shop, and factory from the same water, which has hitherto been thought to constitute the very reverse of fire.

Fire is extinguished by water thrown upon it, because the water cools the burning objects and robs them of the heat necessary for combustion. The light of a lamp is extinguished by being blown into, because the cold air forced upon the light cools it and so prevents the combustion from continuing. In both cases, we see that combustion ceases, as soon as it is robbed of the temperature necessary for its sustenance. If the temperature of the fire be high enough and the amount of water thrown upon it small in proportion, the water will not only

be ineffectual in extinguishing the fire, but will even further and support it. It can easily be noticed that, when a stream of water is thrown into a great conflagration, the vast heat changes the water into steam even before it reaches the objects on fire. If, however, the heat reach a still higher degree, the steam will be expanded to such an extent, that the chemical union of the two elementary substances of water is dissolved, and in place of water two separate gases, hydrogen and oxygen, will reach the flames and nourish the fire instead of extinguishing it. That combustion thus may be furthered by water, is known practically, if not theoretically, to every blacksmith, who sprinkles his coal with water before working his bellows. The great heat produced by the combustion of the coal, when a strong current of air (and hence of oxygen) is forced into them by the action of the bellows, suffices to decompose water into its elementary substances, which are genuine supporters of combustion."

The manner in which the chemical union called combustion takes place having thus been illustrated, we will now proceed to treat more fully of the elements themselves that take part in combustion. We have adopted the style of a catechism, because we believe the method of questions and answers best suited for the purpose of fixing facts on the mind of the average reader. We have also added as many questions and answers on the properties of steam, as we deemed necessary for our purpose.

CATECHISM

OF

COMBUSTION AND STEAM.

I.

What is combustion?

Combustion* is the term usually applied to the process of burning, which consists in the chemical union of several elementary substances.

What is meant by an elementary substance?

An elementary substance is one of those substances in which chemistry is unable to discover more than one constituent.

What is combustion commonly called?

It is called fire. It imparts heat, which has the effect of expanding both fluids and solids. It can

* Combustion is nothing more than an energetic chemical union, or, in other words, it is the mutual neutralization of opposing electricities. When coal is brought to a high temperature, it acquires a strong affinity for oxygen, and a combination with oxygen will produce more and has sufficient heat to maintain the original temperature; so that part of the heat is rendered applicable to other purposes.

We have said that combustion is the mutual neutralization of opposing electricities; what then is electricity? It is a power in nature, evolved in any disturbance of molecular equilibrium whether from a chemical, physical, or mechanical cause; it is a property of force which resides in all matter, from the metal to the gases, and which constantly seeks to establish an equilibrium.—How does the equilibrium of electricity become disturbed? By changes in the condition of matter. As electricity resides in all substances and is perhaps an essential ingredient in their condition, so every change in the state of matter disturbs the electrical equilibrium, and the force exerted by electricity to resume its balance in the scale of nature is in proportion to the degree of disturbance.

not exist without the presence of combustible materials. It has a tendency to diffuse in every direction. It can not exist without oxygen or atmospheric air.

What elements, or elementary substances, take part in the maintenance of a fire?

Hydrogen, *carbon*, and *oxygen*. Hydrogen and carbon exist in the fuel, and oxygen is supplied by the air.

What is hydrogen?

Hydrogen is an elementary substance, which exists in the form of a permanent, colorless, and inodorous gas. One of its most striking peculiarities is its specific gravity, it being the lightest of all known bodies, fourteen and a half times lighter than common air.

Where does hydrogen chiefly exist?

In water, where it exists in combination with oxygen, eleven parts of hydrogen and eighty-nine of oxygen forming water.

What is carbon?

It is also one of the elementary bodies and is very abundant throughout nature. It abounds mostly in vegetable substances, but is also contained in mineral bodies and in minerals. The form in which it is most familiar to us is that of charcoal, which is carbon almost pure.

What is oxygen?

Oxygen, a colorless, inodorous, tasteless gas, is the most abundant and the most widely distributed of all elements. Mixed with nitrogen it constitutes

about a fifth of the bulk, and considerably more than a fifth of the weight of the atmosphere. In combination with hydrogen, it forms eight ninths of all the water on the globe. Owing to the intensity with which it combines with a great many elementary substances, this gas has the power of supporting combustion in an eminent degree.

What is the composition of the air in its natural state?

It consists of oxygen, nitrogen and carbonic acid gas in the proportions of oxygen 20 volumes, nitrogen 79 volumes, and carbonic acid 1 volume.

What is nitrogen?

Nitrogen, a colorless, tasteless, inodorous, permanent gas, which in its appearance in no way differs from the atmospheric air, of which it is the main ingredient, is also one of the most widely diffused elementary substances. It forms about four fifths by bulk of the atmosphere.

Will nitrogen burn?

It will not burn, neither will it support combustion or respiration. A lighted taper introduced into it is immediately extinguished, and animals placed within it soon die.

Why is the oxygen of the air mixed so largely with nitrogen?

Because oxygen in any greater proportion than that in which it is found in the atmosphere, would be too exciting to the animal system. Johnston, the renowned English chemist (b. 1796, d. 1855), says "As a candle burns in oxygen gas with much greater brilliancy and rapidity than in common air, so animals breathe in it with an increase of pleasure;

but it excites them, quickens their circulation, throws them into a state of fever, and finally kills them by excess of excitement. They live too rapidly in pure oxygen gas, and burn away in it like the fast-flaring candle."

What effect has combustion upon the composition of the air?

In combustion the oxygen of the air is absorbed. It has been found that in burning 10 lbs. of coal, the oxygen contained in 1500 cu. ft. of air was altogether absorbed, which will make 150 cu. ft. of air to every pound of coal that is consumed.

What fuel is most in use for general purposes?

The fuel most in use for general purposes is coal.

What are the chemical components of coal?

For all ordinary purposes, it is sufficient to say that coal consists of carbon and hydrogen, but mainly of carbon.

Why does poking a fire cause it to burn more brightly?

Because it opens avenues through which the air may enter to supply oxygen.

Why do "blowers" improve the draught of air through a fire?

Because by obstructing the passage of the current of air above the fire, they cause additional air to pass through it, and a greater amount of oxygen is, therefore, carried to the coal.

What makes combustion apparent to the eye?

Combustion is made apparent to the eye by the flame and smoke attending it.

What is flame?

It is the burning of gas, which takes place only when the temperature is very high.

Does gas burn at all at a low temperature?

It does not; when we throw fresh coal upon the fire, we may hear the gas escape from the coal without taking fire.

Why is this?

The fire being slow, the temperature is not high enough to ignite the gas.

What is the gas which escapes from the coal?

Carburetted hydrogen, a gaseous compound of carbon and hydrogen.

Why will the hydrogen burst into flame, when the coal have become thoroughly heated?

Because the carbon of the coal and the oxygen of the air have begun to unite, and have greatly increased the heat, and have produced a rapid combustion so nearly allied to flame, that it ignites the hydrogen.

What temperature is required to produce flame?

That depends upon the nature of the combustible you desire to burn. Finely divided phosphorus and phosphorated hydrogen will take fire at a temperature of 60 or 70 degrees, solid phosphorus at 140 degrees, sulphur at 500 degrees, carbonic oxide at 1000 degrees (red heat), coal gas, ether, turpentine, alcohol, tallow, and wood at about 2000 degrees (incipient white heat). When once inflamed, they will continue to burn and will maintain a very high temperature.

What is smoke?

Smoke consists of small particles of carbon, of hydrogen gas, and of other volatile matters, which are driven off by the heat and carried up the chimney.

What do small particles of carbon form, when separated from the other constituents of smoke?

They are called soot.

Why do fresh coal when thrown into the fire, increase the quantity of the smoke?

Because they contain volatile matters, which are easily driven off, and because they also reduce the heat momentarily, so that the matter first escaping can not be consumed.

Are all the constituents of smoke incombustible?

Not at all; under proper management the majority of them might be utilized for combustion.

Is it not a waste of fuel to allow these to escape?

It is; the smoke from the numerous chimneys in our large cities daily covers the house tops and streets with soot and coaldust and fills the atmosphere with gases invisible to the eye. This immense waste in the city of St. Louis alone amounts to thousands of tons of coal annually. We are quite convinced that this waste might be done away with almost entirely by better management. We are, furthermore, fully convinced that the "National Electric Furnace" will not only do away with this waste, but will also offer greater advantages for the production of steam than any other known boiler furnace.

II.

What is steam?

Steam is water in the gaseous form.

What are the chemical components of water?

Chemists tell us that water is the result of two gases, known as hydrogen and oxygen, two volumes of hydrogen to one of oxygen, or eight parts by weight of oxygen to one of hydrogen.

What is the volume of steam compared to the volume of water from which it was made?

The volume of steam at 15 lbs. pressure to the square inch or atmospheric pressure is 1700 times greater than that of any given quantity of water from which it may be derived. If 520 cu. ft. of water be evaporated, the volume of steam at atmospheric pressure would be 884000 cu. ft. If analyzed, there would be two volumes, about 589333 cu. ft., of hydrogen to one volume, about 294666 cu. ft., of oxygen. If about two thirds of this volume were utilized or converted into a mixture of fuel, there would be 196444 cu. ft. of oxygen to support combustion, and 392888 cu. ft. of hydrogen would be made to burn.

What is meant by dry steam?

Dry steam is that which is devoid of water held in suspension.

What is meant by superheated steam?

Superheated steam is that which is heated above the temperature due to its pressure.

What is meant by wet steam?

Wet steam is that which holds water in suspension.

What is the sensible heat of steam at atmospheric pressure?

The sensible heat of steam at atmospheric pressure is 212 degrees, that is, it takes 180 degrees of heat to raise water at 32 degrees to the boiling point, and $32° + 180° = 212°$.

What is meant by latent heat?

By latent heat is meant the heat existing in bodies which is not discoverable by the touch or by the thermometer, but which manifests its existence by producing a change of state. Heat is absorbed in the liquefaction of ice, and in the vaporization of water, yet the temperature does not rise during either process, and the heat absorbed is therefore said to become latent. The latent heat, in point of fact, is not uniform at all temperatures; neither is the total amount of heat the same at all temperatures. That the total heat in steam increases somewhat with the pressure, and that the latent heat diminishes somewhat with the pressure, will be made obvious by the following numbers:

PRESSURE	TEMPERATURE	TOTAL HEAT	LATENT HEAT
lbs.	Degrees.	Degrees.	Degrees.
15	213.1	1178.9	965.8
50	281.0	1199.6	918.6
100	327.8	1213.9	886.1

If, then, steam of 100 lbs. be expanded down to steam of 15 lbs., it will have 35 degrees of heat over that which is required for the maintenance of the vaporous state, or, in other words, it will be surcharged with heat.

What is the most economical steam pressure?

The most economical steam pressure is from eighty to ninety pounds to the square inch on the piston of any high pressure steam engine.

What can you tell about the properties of saturated steam?

The following table gives the value of all properties of saturated steam required in calculations connected with steam-boilers.

PROPERTIES OF SATURATED STEAM.

Pressure		Temperature in Fahrenheit Degrees.	Volume		Latent Heat in Fahrenheit Degrees.	Total heat required to generate 1 lb. of steam from water at 32° under constant pressure.
By Steam Gauge.	Total.		Compared with Water.	Cub. Ft. of Steam from 1 lb. of Water.		
						In heat units
0	15	212.0	1642	26.36	965.2	1146.1
5	20	228.0	1229	19.72	952.8	1150.9
10	25	240.1	996	15.99	945.3	1154.6
15	30	250.4	838	13.46	937.9	1157.8
20	35	259.3	726	11.65	931.6	1160.5
25	40	267.3	640	10.27	926.0	1162.9
30	45	274.4	572	9.18	920.9	1165.1
35	50	281.0	518	8.31	916.3	1167.1
40	55	287.1	474	7.61	912.0	1169.0
45	60	292.7	437	7.01	908.0	1170.7
50	65	298.0	405	6.49	904.2	1172.3
55	70	302.9	378	6.07	900.8	1173.8
60	75	307.5	353	5.68	897.5	1175.2
65	80	312.0	333	5.35	894.3	1176.5
70	85	316.1	314	5.05	891.4	1177.9
75	90	320.2	298	4.79	888.5	1179.1
80	95	324.1	283	4.55	885.8	1180.3
85	100	327.9	270	4.33	883.1	1181.4
90	105	331.3	257	4.14	880.7	1182.4
95	110	334.6	247	3.97	878.3	1183.5
100	115	338.0	237	3.80	875.9	1184.5
110	125	344.2	219	3.51	871.5	1186.4
120	135	350.1	203	3.27	867.4	1188.2
130	145	355.6	190	3.06	863.5	1189.9
140	155	361.0	179	2.87	859.7	1191.5
150	165	366.0	169	2.71	856.2	1192.9
160	175	370.8	159	2.56	852.9	1194.4
170	185	375.3	151	2.43	849.6	1195.8
180	195	379.7	144	2.31	846.5	1197.2

What is the power of boilers?

Regarding the power of boilers, it may be stated that a boiler 30 ft. long and 3 ft. in diameter will afford $30 \times 3 \times 3.14 \div 2 = 141.30$ sq. ft. of heating surface, or steam for 14 horse-power. The term horse-power has been applied to boilers, and has been used so long in connection with them, that it will probably "stick," so we must make the best of it. This can only be done by assuming some standard evaporative power for a measure and rating boilers accordingly. Such a standard was recommended by the judges at the Centennial in 1876. This standard is: *The evaporation of thirty pounds of water per hour from feedwater, having a temperature of 100° Fahr., into steam, having a pressure of seventy pounds per square inch above the atmosphere, is equal to one horse-power.*

If a boiler, fitted with 18—6 in. flues, 60 in. in diameter, 18 ft. long, contain 697 sq. ft. heating surface, why is it rated 58.1 horse-power?

Because it requires the above boiler to evaporate the necessary amount of water to furnish steam for the above power in an ordinary good steam-engine.

Why can not the size of boilers and the space of furnaces be reduced and more water be evaporated per hour?

It can. The "National Electric Furnace" will accomplish it. The improvement set forth in this furnace, its merits, its working, and the advantages of same over any other furnace ever invented, of which we have any knowledge, will be explained subsequently. We shall now refer to the ordinary steam-boiler furnaces, their disadvantages, and the experiments made to remedy the latter.

Ordinary Steam-boiler Furnaces.

For years great progress has been made in the improvement of boilers and engines, while the construction of furnaces for setting boilers has been left to the judgment of any mason, each setting his own way. But we are pleased to see a change taking place and steam-users paying closer attention to the details of their boiler setting, and looking for devices by which the disadvantages and great waste accompanying ordinary steam-boiler furnaces might be avoided. But what are the disadvantages of the ordinary steam-boiler furnace, and how is the great waste going on? That is just what we shall try to explain in the following.

In an ordinary steam-boiler furnace, fire is built upon the grate, and air is admitted through the grate into the fuel, the oxygen of the former being needed to support the fire. It is, however, a wellknown fact that not one-third of the amount of oxygen required for perfect combustion passes through the body of the fuel; this produces carbonic oxide, which usually passes away unconsumed, since the flames of the fire impinge directly on the boiler-plate, the temperature of which (at common steam pressure) is below 400 degr. Fahr. Consequently the unburnt gases escaping from the fuel pass on out of the chimney and are wasted. If we wish to burn the carbonic oxide in a furnace, we should supply a certain weight of highly heated oxygen

above the grates, but this can not be done in ordinary furnaces, since atmospheric air, the source of oxygen as a supporter of furnace combustion, is admitted through the registers in the furnace door. Besides the opening of the door in firing of fresh coal allows the cold air to rush in through the whole length of the furnace, depriving the walls of a great amount of heat and cooling down the interior space, so that considerable time must elapse after the doors are closed before the fire is glowing and the former high temperature in the furnace is restored. This disadvantage of the ordinary steam-boiler furnace not only wholly prevents the combustion of gases at the time, but also causes a direct loss of fuel, as will be perceived by the following.

In all soft coals, there are found compounds of carbon and hydrogen known as hydro-carbons, which must also pass into the gaseous condition before being burned. If these hydro-carbons, such as pitch, tar, naphta, etc., are mixed on first issuing from the coal with a large quantity of air, these inflammable gases are completely burned with a transparent blue flame, producing carbonic acid and steam, but if raised to a red heat, before being mixed with air enough, they disengage carbon in fine powder, and the higher the temperature, the more carbon they disengage. If this disengaged carbon is cooled below the temperature of ignition, before coming into contact with oxygen, it constitutes, while floating in gas, smoke, and when deposited on solid bodies, is soot. But if this disengaged carbon is maintained at the temperature of ignition, and supplied with oxygen sufficient for its combustion, it burns, while floating in the inflammable gas, with a red, yellow, or white flame. The flame from fuel is the larger, the more slowly its combustion is

effected, and with the colors of flame given above, as the combustion is less or more complete. An example of this is found in the use of common illuminating gas, when burned with a "Bunsen" or with a common burner. The chilling of the gaseous hydro-carbons, which are driven off from the solid pieces of coal by the heat developed, takes place in two ways in ordinary furnaces: either by coming in contact with a cold body as the iron of the boiler, or by finding too much cold air in the furnace.

But have there been no devices to avoid these disadvantages and utilize this waste?

For the past thirty years, or more, experiments have been made to utilize this immense waste. Various experiments have been made to save this loss by the use of atmospheric air above the fire, the principal method being to introduce cold air. But this results in a loss, for the air must be raised in temperature to about eight hundred degrees of Fahr. to produce combustion. Later furnaces have been invented to preheat the air to a high degree, before joining it with the gases, and thus save taking so many units of heat from the flames.

Various devices have been adopted to preheat the air. Some have admitted air through the bridgewall. Others have admitted the same by small flues in front and then conducted it through a number of horizontal expanding ducts, in which it passes backward and forward, until finally in a heated state, it enters at the sides and bridgewall of the furnace, and unites with the product of combustion. Whenever this was done, it was invariably at the cost of economy, because the brick walls absorb heat from the gases and flames, and conduct it to the cold air passing through the airducts. Others have adopted the fireclay arches over the

fire space and back of the bridgewall to admit air above the grates. Steam jets have been placed above fire-front door and back of bridgewall to force air and steam above grate.

Most of these devices, however, have progressed very little in the accomplishing of the aim for which they were intended, and the immense waste is still going on.

Smoke burning, or smoke preventing rather, is also attracting no little attention at present in this country, owing largely, perhaps, to the stringent laws on the subject enforced by some cities against the nuisance. It will, however, not be far from the truth to say that there is no successful device in use for smoke prevention, although strong claims are made for several. We shall refer to ordinary illuminating gas in order to show the causes of smoke and the reason why smoke-preventing devices have hitherto met with such poor success.

Ordinary illuminating gas is made by heating coal in a closed vessel. The gas thus given off is that which in a furnace is needed to supply the necessary air and heat to effect combustion. This gas unmixed with the air, will not burn, but when allowed to escape from a burner and supplied with the air in the room, it ignites, if a flame be touched to it. If a burning gas jet be exposed to draught from an open door or window, it smokes, because the supply of air is too great, the heat is insufficient; and it therefore appears that a too plentiful supply of air is as detrimental as too little. It is also stated that if coal gas and air be placed together in a vessel, it will take considerable time for it to mix thoroughly unless assisted by violent agitation or mechanical means. When the great velocity of the gases in the furnace and the short time occupied

by them in passing from the coal to the flues is considered, the difficulty of mixing the air with them will be appreciated. It is also necessary to mix the air with the gases as close to the fire as possible in order that the mixture may have sufficient heat to allow of burning. All smoke preventing devices which allow of the admission of air at the top of the fire box or in another chamber are necessarily ineffective to a greater or less extent owing to this fact, that is, the mixture is too cool to burn. Gas is given off in variable quantities, depending on, whether the coal is green, half, two-thirds, or more burned, and the supply of air must be in proportion. Hence, for perfect combustion of the gases and without smoke, the supply of air should constantly change, which is manifestly impossible in ordinary furnaces. Smoke once formed is not inflammable, and the term "smoke burning" is absurd.

The enormous waste, imperfectly understood by most men of science, is scarcely thought of by the great mass of people. The composition of the air is also very unfavorable to a good result, since it is but poorly adapted to combustion, because its oxygen, the only combustible element in it, constitutes but one fifth of its volume, while the nitrogen, representing four fifths, is not only useless in combustion, but retards it and absorbs a large proportion of the heat of the fire. Under skillful superintendence the quantity of air used is 150 cubic feet to each pound of coal, or 300000 cubic feet for a ton. Therefore, if an establishment fire about seven tons of coal per day, 2100000 cubic feet of air would be required for combustion. Of this vast amount 1680000 cubic feet are useless nitrogen passing into the furnace cold and out of it hot.

If the excessive use of air is unavoidable even in the most perfect furnaces under scientific supervision, and occasions so extensive a loss in heat, it may be inferred how great a waste of heat must occur from this single cause in furnaces and chimneys imperfectly constructed and under the ignorant management of unskillful men.*

On the other hand if too little air is used a partial conversion ensues, and a large proportion of most valuable combustible gases drifts out of the furnace into the atmosphere.

But how may the reformation of so glaring an evil be effected, and both the primary and secondary loss, already explained, be reduced?

The "National Electric Furnace" will effect this reformation. Instead of air it will introduce a mixture of steam, hot air, and gases, into the fuel, by which the bad influence of nitrogen is greatly avoided, because the water, unlike the air, is composed entirely of combustible gases, oxygen and hydrogen. The following pages will give an accurate description of the furnace, then its operation will be shown, and lastly a few directions will be added, followed by a few remarks on the advantages of the furnace.

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* It is true, the heat is not wholly lost, but is required in the chimney of ordinary boiler furnaces for producing a draught. For the chimney is a kind of blower, the same as a chimney on a coal-oil lamp, the more heat in a chimney, the more air forced through the furnace. But, as we have already stated, the velocity of the air in passing through the furnace, results in the escape of a great amount of valuable gases, which are carried off by the air without being ignited, and are therefore wasted. If, however, too little air is used, the combustion is too slow, and the heat in the furnace and flues insufficient to burn the gases and hydro-carbons.

So it is readily seen that a chimney is an expensive apparatus. Just look at it; the black clouds and fogs of smoke in the atmosphere over our largest cities, what are they? Nothing else but wasted coal. It is stated that in an ordinary furnace the waste of fuel is all the way up from 25 to 50 per cent.

THE

National Electric Furnace.

AIMS AND ADVANTAGES.

1. Will do about *double the work* of any ordinary good furnace.
2. *Evaporate more water* per pound of coal.
3. Burn more coal per square foot of grate.
4. *Increase in horsepower* per square foot of grate.
5. Will greatly improve the burning of anthracite coal.
6. Cause even draught.
7. Secure even temperature.
8. Easily adjust the amount of oxygen and gases.
9. Avoid an excess of heat.
10. Steam quicker and easier.
11. Generate drier steam (more powerful).
12. Occasion no waste of fuel or heat.
13. Will never permit cold air to reach grate bars or flues.
14. Grate bars will not warp.
15. Require no poking.
16. Cause no clinkers.
17. Need no flue cleaning.
18. Less attention necessary for firing.
19. Leave lighter, finer ashes.
20. Produce a *continual circulation* of gases.

21. Create a more uniform temperature in furnace, flues, etc.
22. Convert steam (exhaust steam) into gaseous condition.
23. Make use of mixing apparatus and fan as a regulator of furnace combustion.
24. Avoid an excessive heating of incombustible air (Nitrogen).
25. Make the heat and flame more intense throughout the boiler-flues.
26. Prolong the life of the boiler.
27. Protect the neighborhood against the annoying and deleterious clouds and fogs of smoke.
28. Dispense with large expensive chimneys.
29. Occasion no back-pressure on engine by reason of the suction of the fan drawing into the mixer the exhaust steam from the engine, thus creating a partial vacuum in the exhaust pipe.
30. Can be readily adapted to all types of boilers.

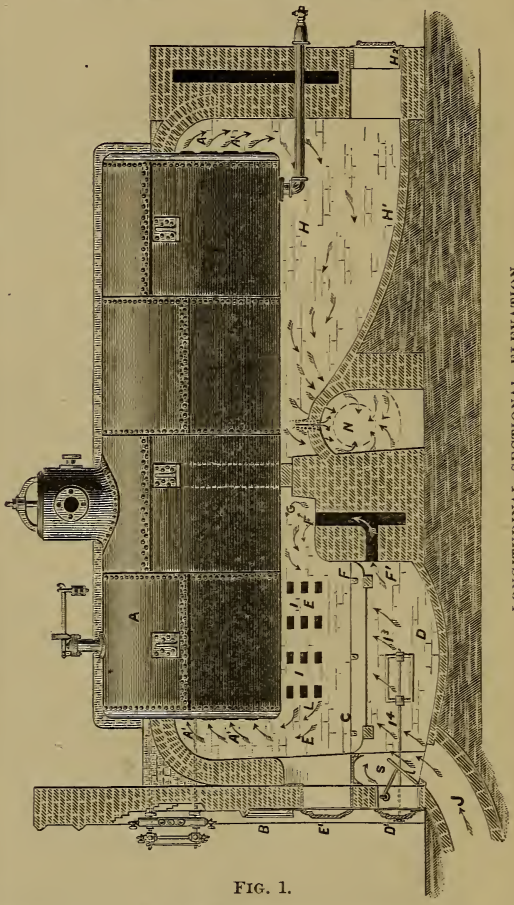
DESCRIPTION.

The object of this invention is to provide a new and improved furnace for steam boilers and for other purposes, in which a complete combustion of the fuel is accomplished by introducing a mixture of steam, hot air, and gases into the fuel.

The invention consists in a specially constructed furnace and chimney, and in an apparatus for forcing a mixture of hot air, steam and gases into the fuel.

The invention also consists of various parts and details, as will be fully described hereinafter. The following five cuts show different views of the furnace, and will serve to illustrate the subsequent description.

NATIONAL ELECTRIC FURNACE.



LONGITUDINAL SECTIONAL ELEVATION.

FIG. 1.

SECTIONAL PLAN VIEW.

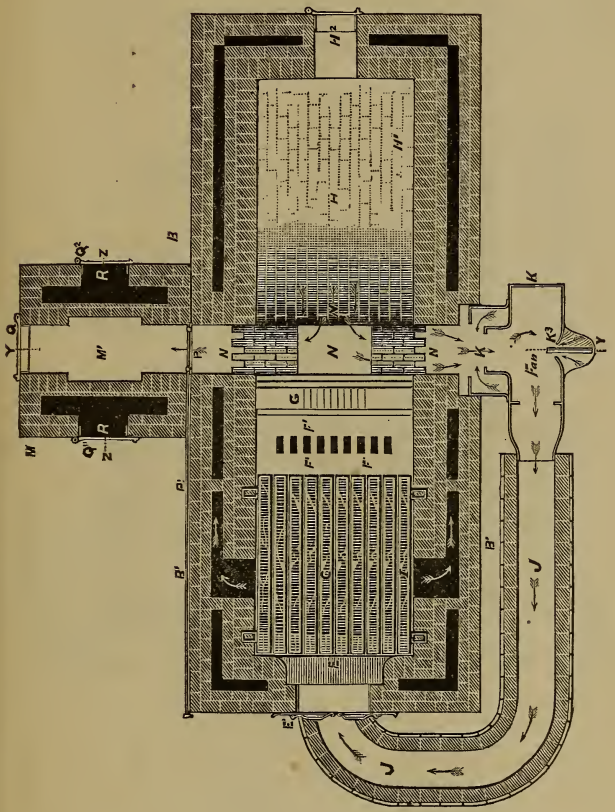


FIG. 2.

CROSS SECTIONAL ELEVATION AND SECTIONAL ELEVATION OF CHIMNEY.

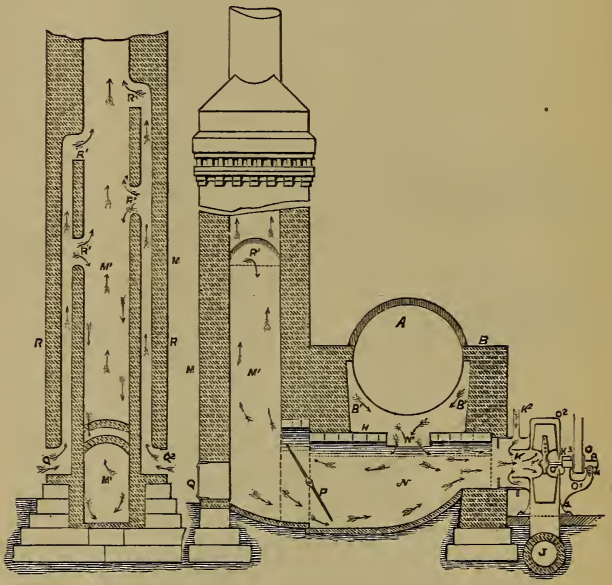


FIG. 4. FIG. 3.

CROSS SECTION.

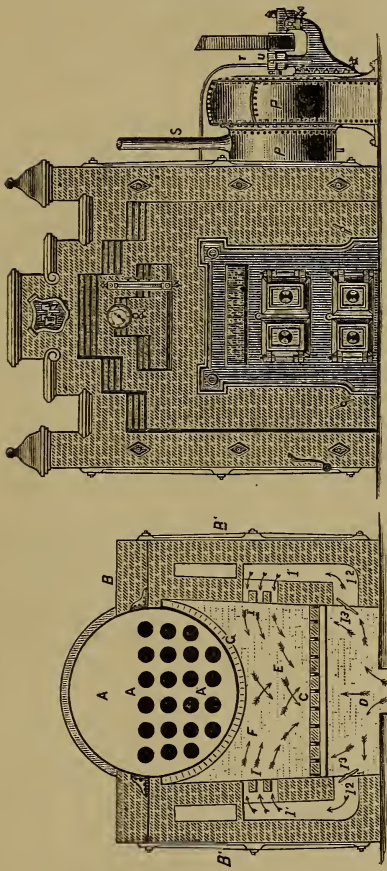


FIG. 5.

Figure 1 is a longitudinal, sectional elevation of the improvement.

Figure 2 is a sectional plan view of the same on the line x—x Figure 1.

Figure 3 is a cross sectional elevation of the same on the line y—y Figure 2.

Figure 4 is a sectional elevation of the chimney on the line z—z Figure 2.

Figure 5 is a cross section on the line v—v Figure 1..

The steam boiler A (Fig. 1), of any approved construction, is mounted in the furnace B provided with the usual grate bars C, the ash-pit D, the doors D^1, leading to the ash-pit, and the doors E^1 opening into the combustion chamber E above the grate bars. The bridge wall F, at the inner end of the grate bars C, is provided with a partition wall G, which divides the furnace into two main compartments, the combustion chamber E and the hot air chamber H. The bridge wall F is provided with several flues F^1, which commence under the grate bars C, run inward and then upward, and open into the combustion chamber E at the rear of the grate bars C.

In the side walls B^1 (Fig. 5) of the furnace B are ducts or flues I^2, which lead from the ash-pit D to the vertical passage I^1, which connects at its top by the flue I with the combustion chamber E. The flue I^2 is provided with a damper I^3, which can be opened or closed from the front of the furnace by a damper rod I^4 (Fig. 1).

Into the bottom of the ash-pit D (Fig. 2) opens a flue or duct J which connects with the mixing apparatus K placed on the outside of the side wall B^1, and connected with the hot air chamber H and a chimney M by the transverse channel N. The latter is arched at two or more places, so as to reduce the opening N^1 leading from the hot air chamber H into

the channel N. The hot air chamber H is provided with a bottom H^1 which is curved upward from the rear end toward the channel N, and is also provided with a door H^2 through which ashes and cinders which accumulate in the hot air chamber H can be removed.

The mixing apparatus K (Fig. 3) consists of a fan K^1, which is rotated in any convenient manner, into which apparatus opens a pipe K^2 admitting steam, and it is also provided with an opening K^3, through which air can pass into the fan from outside. The heating of the journal box O of the mixing apparatus K is prevented by the circulation of cold water around the fan shaft O^1 in the journal box O, said water being supplied by a small pipe O^2 and drawn off through the pipe O^3.

The channel N is provided at its entrance to the chimney M with a hinged damper P operated from the front of the furnace by the damper rod P^1 (Fig. 1). The chimney M is provided on its three outer sides with doors Q, Q^1, and Q^2 (Fig. 3 and 4), of which the door Q (Fig. 3) leads directly into the central chimney opening M^1, while the doors Q^1 and Q^2 (Fig. 4) connect with the vertical side flues R, which open into the central opening M^1, by means of the apertures R^1.

The opening of the flue J (Fig. 1) into the ash-pit D can be closed by the door S so as to prevent ashes and cinders from falling into the said flue when being removed from the ash-pit.

The operation is as follows:

The flames and heated gases from the fire on the grate bars C rise and lap upon the sides of the boiler, and on the front end of the same in the combustion chamber E. The heated gases and flames

enter the boiler flues A^1 at the front end of the boiler A, and, passing through the same, enter the hot air chamber H, from which they are drawn up the inclined bottom H^1 into the channel N by the suction of the fan K^1 and the draught of the chimney M. That portion of the unconsumed products of combustion which passes into the chimney is drawn thereinto by the draught or circulation set up by the action of the fan, the same consisting in the current of air forced from the fan through the pipe J, into the chamber D, through the passages I^2, I^1, I, into the chamber E, thence through the boiler tubes and into the hot air chamber H, whence the same will be forced through the opening N^1 into the channel N, above the damper P, and into the central opening or passage M^1 of the chimney, passing thence into the open air.

The remainder of the heated products consisting of combustible gases and hot air, passes into the mixing apparatus K, where it is mixed by the action of the fan K^1 with the steam (generally exhaust steam) entering through the pipe K^2 and with the fresh air entering from the chimney M. This mixture is then diverted into the flue J and enters the ash-pit D, from which part of it passes directly through the grate C into the burning fuel, part enters the flues F^1 and passes from the rear into the combustion chamber E and over the fuel on the grate bars C, and part of the mixture passes into the side passages I^1 and up through the same and enters the combustion chamber E by means of the openings I. The amount of the mixture which enters the side passage I^1 can be regulated by the damper I^3. The heated products or gases pass then from the combustion chamber into the flues A^1 of the boiler A, as before described. The outside

air is drawn into the chimney by reason of the suction of the fan, the same, as before stated, taking or drawing into the mixer a portion of the products of combustion and forcing or sending it into the chimney as above described, thus creating a partial vacuum in the chimney, assisting the downward passage or entrance of the air from the side-ducts R of the chimney into the central opening M^1 thereof, while the inlet to the channel N from the chimney is of greater area than the inlet thereto from the hot air chamber H, whereby the cold or fresh air currents which are heavier than the warm air currents will descend, passing closely along the sides of the chimney and the bottom of the channel N, under the valve P, whence it passes into the suction side of the mixer, thus effecting the aforesaid result.

Air from the outside can enter the chimney M by the side doors Q^1 and Q^2, and after passing up the side flues R enters the central opening M of the chimney, forced downward in the same by the suction of the fan K^1, and is heated in this downward motion by the incombustible and unconsumed gases passing up the central shaft M^1, as before described.

The complete combustion of the fuel is thus attained by our improved furnace, the combustible gases being forced from the hot air chamber into the combustion chamber, and being additionally charged with a mixture of steam and air.

Directions:

In starting the furnace, build your fire upon the grate as usual. Open the damper in the channel to the chimney to give sufficient draught, and close the doors in the vertical side flues of the chimney. See that the dampers in the flues of the side walls are closed. Admit the air through the ash-pit doors

to support combustion. When sufficient steam is generated for the proper pressure to start the engine, set the dampers and then start the mixing apparatus or fan. When it is in operation, open valve in exhaust pipe to admit a sufficient volume of steam into the mixer. Keep the doors in the furnace front closed. Regulate the damper in the air-ducts of the side walls to admit more or less of the mixture above the grate. Set the damper to chimney in its proper place to admit a sufficient volume of fresh air and to allow the unconsumed and incombustible air to escape. Be careful not to waste. The engineer will soon learn its working.

The great waste of heat avoided.

In an ordinary furnace, the gases and flames pass on over the bridge wall to the rear end. The stream of heat and flames heats the boiler above and the bottom floor of furnace below, the latter absorbing considerable heat for no benefit whatever. The artificial forced draught in the "National Electric Furnace," however, will assist the fire in the combustion chamber by compelling the flames to lap upon the sides and end of the boiler, so that the heat will be forced through the flues and generate steam (dry steam) with greater effect.

The exhaust steam utilized.

In most all furnaces in which steam is used for power, the exhaust steam is more or less wasted, except what is used for heating feed-water, and in some cases, for heating the building, etc. In an ordinary good engine, where power is used to an extent, about one third, more or less, of the exhaust

steam is sufficient to heat the feed-water,* while two thirds, more or less, can be made useful for fuel, the hydrogen to burn, and the oxygen to support combustion. Why is not all of this heat and gas utilized instead of being wasted? The cause is that hitherto there has been no successful device to utilize it. The "National Electric Furnace" for steam boilers, however, will utilize nearly all of the gases and heat, that have hitherto been wasted. Instead of air, it will make use of a mixture of steam, hot air, and gases for combustion. The heated product of combustion in the furnace, consisting of combustible gases and hot air, is forced into the mixing apparatus, where it is mixed with the exhaust steam by the action of the fan. The hot air and gases forced into the mixing apparatus absorb the steam, as it enters the apparatus. This

* The *Fuel Economizer* which has been largely used in England, has been improved and adopted in this country. It is confidently presented to the public as the very best thing of the kind at present known. There are two sources of waste in all steam boilers which may in a measure be made to neutralize each other. The gases going to the chimney carry off on an average, according to good authority, 31 percent more or less of the fuel, in the most economical boilers. The feed-water has to be heated from the normal temperature to that of steam before evaporation can commence, and this is generally done at the expense of the fuel which should be utilized in making steam. This temperature, at 75 lbs. pressure, is 320°, and if we take 60° as the average temperature of feed, we have 260 units of heat per pound which, as it takes 1151 units to evaporate a pound from 60°, represents a loss of 22.5 percent of fuel. All of the heat, therefore, which can be imparted to the feed-water, from the waste heat in the escaping gases, is just so much saved. Now the *Fuel Economizer* consists of a series of vertical tubes placed in a brick chamber, which forms part of the flue between the boiler and the chimney, and through which all the hot gases are caused to pass. The feed-water is forced and enters at one end of the connecting pipe, then travels through a series of vertical tubes, so that it is possible to heat the water very nearly to the temperature of the escaping gases before it flows to the boiler.

The exhaust steam, however, from nearly all steam engines is mostly wasted, as has been stated above, but in our case, if the Economizer be adopted for heating the feed-water, the exhaust steam could be utilized for combustion to an extent and thus nearly all escape gases saved.

mixture is then forced through and above the grate into the combustion chamber. Whatever part of the mixture is not ignited at the first circulation, on account of not having been thoroughly mixed, is forced through the flues mingled with other gases into the hot air chamber, and thence to mixer for second circulation, and so on.

The cost of the fan quite outweighed by the saving.

Objection may be raised regarding the cost of running the fan or a blowing engine. But the draught of the chimney assists the fan to raise the incombustible and unconsumed air out of the chimney, and the fan is, therefore, required to run at moderate speed only, less than if only atmospheric air were used to support combustion. Besides, the gain acquired by using an atmosphere of steam, hot air, and combustible gases in the National Electric Furnace, and so avoiding the heating of a vast amount of incombustible air (nitrogen) which takes place in an ordinary furnace, nearly cancels the expenditure of running a fan or blower. Then another saving results from the mixture itself, since it creates a new water-gas fuel (carburetted hydrogen) and produces a continual circulation in the furnace, the violent agitation by mechanical means mingling and mixing the fine particles of carbon and other volatile matters, and the product so created being continually regenerated with a new supply of fresh hot air and steam, etc., as explained before. This combination of gases enables a more perfect combustion than takes place in ordinary furnaces and will accomplish a saving of fifty per cent. more or less.

The backpressure diminished.

There is still another gain to overcome the cost of power to run the mixing apparatus. The blower (or fan) draws the exhaust steam from the engine and so diminishes the back pressure by creating a partial vacuum in the exhaust pipe.* This will clearly show that by using artificial draught and so utilizing all the wasted gases, the National Electric Furnace fully overcomes the cost of running the fan.

The advantage of the "National Electric Furnace" of other furnaces with artificial forced draught.

What advantage has the "National Electric Furnace" of other furnaces with artificial forced draught? Other furnaces with artificial forced draught make use only of atmospheric air and produce a great waste. They force large amounts of air through the grate, but the velocity of the air in

* It is stated, that a condenser by condensing the exhaust steam from an engine, diminishes the backpressure by creating a partial vacuum behind the piston. This vacuum is generally spoken of as being of so many inches of mercury, each inch of mercury representing a diminution of half a pound in the backpressure. Thus, a vacuum of twenty-six inches means that the backpressure has been reduced thirteen pounds per square inch; or, that instead of the engine working against a resistance equal to the pressure of the atmosphere (about fifteen pounds per square inch), it is working against a resistance of only two pounds per square inch. A vacuum of twenty-six inches, however, can not always be obtained, but one of twenty inches may be safely assumed with almost any condenser. Diminishing the backpressure ten pounds per square inch has the same effect as adding ten pounds per square inch to the mean effective pressure of the engine. In other words, if an engine, while working against a backpressure equal to the pressure of the atmosphere, has a mean effective pressure of thirty pounds, it will have a mean effective pressure of forty pounds per square inch when the condenser is attached. In this case, other things being the same, the engine would be able to do exactly one-third more work with the aid of the condenser than without it.

If a steam condenser, as above stated, has such effect, how much greater must the effect of a blower (fan) be, which *forces* the exhaust steam from an engine, thus creating a greater partial vacuum behind the piston than the condenser.

passing through the fuel being so great, the result is, that great volumes of gases pass on unconsumed and leave by way of the chimney. The "National Electric Furnace," however, returns these products, mixes them with steam and air, forces them into the fuel at the required degree of heat, and so produces perfect combustion. In this manner it accomplishes an increase in horsepower per square foot of grate, burning more coal per square foot of grate, evaporating more water per pound of coal, and hence requiring less boiler and furnace space. It will, therefore, do double and more work in generating steam, will burn all kinds of fuel, and will greatly improve the burning of anthracite coal. The hydrogen gas given off in the burning of bituminous coal is that which in a furnace is necessary to supply the necessary air and heat to effect combustion. The mixture of steam, hot air, and gases consists greatly of hydrogen and thus gives to the anthracite coal that, which will make it more illuminous and increase its power.

Other advantages.

The operation of this furnace by mechanical means will also cause a uniform temperature, a steadier. evaporation, less firing, less labor, less wear and tear, and hence less repairs.

The "National Electric Furnace" can be worked like other forced draught furnaces, or even like an ordinary steam-boiler furnace, as occasion requires.

It is also quite obvious that the National Electric Furnace can be operated without the use of steam in the mixing apparatus. If, for instance, from

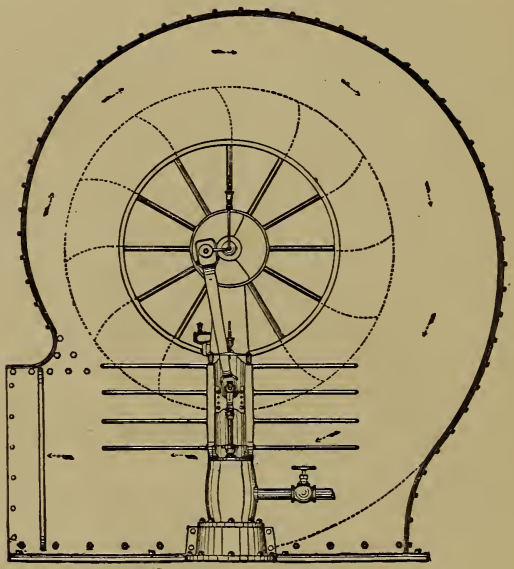
any cause the entire exhaust steam should for the time being be required for other purposes, the supply of steam to the mixing apparatus can be simply cut off, and the apparatus will work on all the same, in such case performing the office of a blower of a natural forced draught furnace. Even the mixing apparatus may totally suspend operation, while the furnace performs its work like an ordinary boiler furnace by means of the draught of the chimney, with the advantage, however, that its combustion chamber and hot air chamber are separated, so that the air can not rush through the whole length of the furnace at once and carry off so much valuable combustible matter, as it does in ordinary steam boiler furnaces.

The plant of the "National Electric Furnace" may be varied.

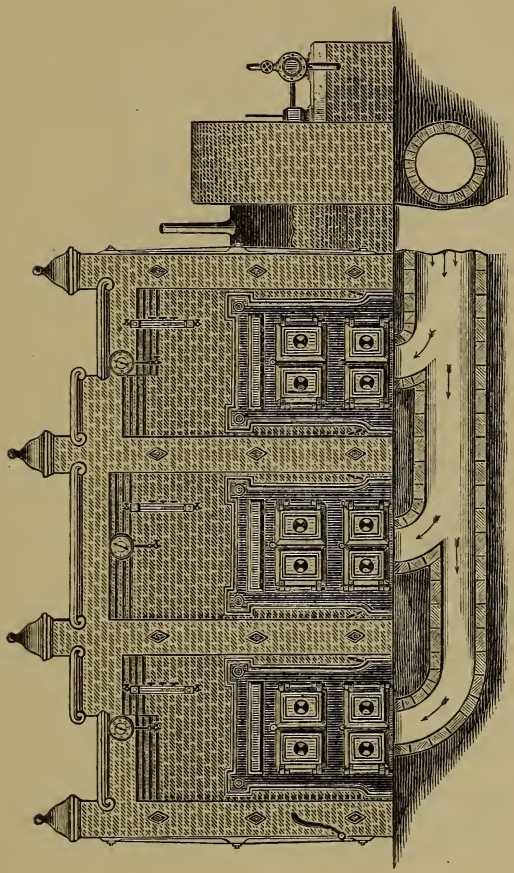
The plant of the furnace may be varied in construction. The airducts that connect the fan with the ash-pit can be placed underground and be made of brick or other material. The fan or mixing apparatus can be placed at any suitable place by extending the air channel. The fan can be run by a belt from a near shaft. A mixing apparatus combined with a blowing engine, (See p. 42) now made at a very reasonable price, would be preferable. The chimney can also be a distance from the furnace by extending the air channel. Old chimney can be used.

The "National Electric Furnace" may be adapted to any boiler.

The improvement is not confined to one class of boilers only, but can be adapted to any boiler of any



The above illustration represents a fan combined with a blowing engine, which we highly recommend for adoption, whenever the latter is to be combined with the mixing apparatus of the "National Electric Furnace." In operating the furnace, especially the larger size, the work of the blower is most steady and regular, and the fan can be regulated at will to run at a high or low speed, according to the increase or decrease of combustion required in the furnace for the evaporation of steam. These blowing-engines are superior to the common run of mill engines in point of strength and workmanship. They are made to stand twenty-four hours continuous work six days in the week, and to run at any speed without getting out of order. They are manufactured by different parties, the above engraving representing a style manufactured by B. F. Sturtevant, Boston.



BATTERY OF BOILERS.

approved construction. The engraving (See p. 28) represents only one style, but all that is needed to adapt the improvement to boilers of various construction, is to arrange it so that the heat and flames will be applied to the heating surface in such a manner, as will be most effective. The boiler is simply mounted in the furnace; the combustion chamber is to be built up with white fire brick, and the air-jets or flues in bridge- and sidewalls are to be made the size of one brick in height and width.

The "National Electric Furnace" may be applied to a battery of boilers.

The improvement can also be very readily applied to a battery of boilers, (See p. 43) and with a marked better result in regard to the cost of operating it.

By comparing the following tables, the advantages of the "National Electric Furnace" over ordinary good furnaces in the developing of horse-power,* etc., may be plainly seen.

---

* When Watt began to introduce his steam engines, he wished to be able to state their power as compared with that of horses, which were then generally employed for driving mills. He accordingly made a series of experiments, which led him to the conclusion that the average power of a horse was sufficient to raise about 33000 lbs. one foot in vertical hight per minute, and this has been adopted in England and this country as the general measure of power.

Hence, if an ordinary well-constructed boiler can at a moderate heat furnish sufficient steam for pressure to drive an engine so that it will raise a weight of about 33000 lbs. one foot in vertical height per minute, it is said to be equal to about one horse-power.

The best engines and boilers develop a horse power per hour by the consumption of two pounds of coal. But this is better than the average, and three lbs. of coal per hour for a horse-power is a more common result.

The "National Electric Furnace"

with artificial forced combustion will accomplish on an average

per 20 Minutes:

PROPORTION—Horse-power; heating and grate surface; coal consumed; water evaporated; steam generated; two-thirds more or less of the exhaust steam converted into a mixture for fuel; half of the combustible gases and hot air, more or less, taken from the hot air chamber; total mixture forced into the combustion chamber.

Horse-power.	Square feet of heating surface.	Square feet of grate.	Pounds of coal.	Cubic feet of water.	Cubic feet of steam generated.	Two-thirds of exhaust steam in cubic feet for consumption.	If analyzed for Consumption			Total.
							Contains two volumes of hydrogen in cubic feet.	And one volume of oxygen in cubic feet.	Regenerating half of the product hot air and gases in cubic feet.	The mixture forced into the fuel in cubic feet.
1	10	3/8	2 1/2	1	1700	1133	755	378	1133	2266
5	50	1 7/8	12 1/2	5	8500	5665	3775	1890	5665	11330
10	100	3 3/4	25	10	17000	11330	7550	3780	11330	22660
20	200	7 1/2	50	20	34000	22660	15100	7560	22660	45320
30	300	11 1/4	75	30	51000	33990	22650	11340	33990	67980
40	400	15	100	40	68000	45320	30200	15120	45320	90640
50	500	18 3/4	125	50	85000	56650	37750	18900	56650	113300
60	600	22 1/2	150	60	102000	67980	45300	22680	67980	135960
80	800	30	200	80	136000	90640	60400	30240	90640	181280
100	1000	37 1/2	250	100	170000	113300	75500	37800	113300	226600

NOTE.—The above calculations have been gained through some reliable information, and from scientific papers. They were theoretically calculated, and the figures will give nearly the results, although these may vary in figures a little below or above the amount. The furnace can be regulated more or less by mechanical operation.

An Ordinary Good Furnace

with natural draught will accomplish on an average

per 60 Minutes:

PROPORTION—Horse-power; heating and grate surface; coal consumed; water evaporated in pounds, gallons, or cubic ft.; amount of atmospheric air required for combustion, in cubic feet; volume of oxygen ($\frac{1}{5}$ of atmospheric air) supporting combustion, in cubic feet; volume of nitrogen in cubic feet ($\frac{4}{5}$ of atmospheric air) as a waste of heat passing into the furnace cold and out of it hot.

Horse-power.	Square feet of heating surface.	Square feet of grate.	Pounds of coal.	Pounds of water, or	Gallons of water, or	Cubic feet of water	Cubic feet of atmospheric air necessary.	If analyzed contains	
								One volume of oxygen in cubic feet.	Four volumes of nitrogen in cubic feet.
1	15	5/8	7½	62½	7½	1	1125	225	900
5	75	3⅛	37½	312½	37½	5	5625	1125	4500
10	150	6¼	75	625	75	10	11250	2250	9000
15	225	9⅜	112½	937½	112½	15	16875	3375	13500
20	300	12½	150	1250	150	20	22500	4500	18000
25	375	15⅝	187½	1562½	187½	25	28125	5625	22500
30	450	18¾	225	1875	225	30	33750	6750	27000
40	600	25	300	2500	300	40	45000	9000	36000
50	750	31¼	375	3125	375	50	56250	11250	45000
60	900	37½	450	3750	450	60	67500	13500	54000
80	1200	50	600	5000	600	80	90000	18000	72000
100	1500	62½	750	6250	750	100	112500	22500	90000

NOTE.—These calculations are generally believed and accepted; they have been collected from reliable sources with much care.

We are aware of the difficulty of overcoming old established customs. The time, however, is not far, when manufacturers and steam users, instead of diffusing their valuable combustible gases into the atmosphere, will gladly adopt a device for utilizing all that is now wasted in regard to fuel and so do away with the smoke nuisance. As long as there is no device, however, "smoke ordinances," which some cities have adopted, can not and will not be enforced. The "National Electric Furnace," however, will, as we sincerely hope, through its merits soon convince the public of the possibility of preventing all of the waste going on in combustion and of doing away with the smoke nuisance.

The "National Electric Furnace Co." owns the above furnace, and its rights are controlled and protected under Letters Patent No. 350245, granted to G. Hasecoster, October 5th, 1886. Plans, specifications, etc. will be furnished upon application. For further information apply to "National Electric Furnace Co.," St. Louis.

Artificially Forced Combustion.

The idea of making use of artificial draught for the purpose of increasing the amount of coals capable of being burned per square foot of grate, is by no means a new one, as will be shown by the following, which we have abstracted from an article in the "*Mechanical Engineer.*"

"The value of space in the merchant steamer for carrying cargo, and in the vessel of war for coal capacity, whereby her ability to keep the sea or steam long distances may be increased has induced many experiments with different methods of artificial draught. Of the steam-jet in the smoke-stack and beneath the grates we have had an endless variety, and of the air-blast at both the above places there have been various plans. While these have been more or less successful in improving the draught, it has been generally at a complication of detail and waste of steam; so it may be asserted that there are but two practical plans that effect the purpose of increasing the amount of coals capable of being burned per square foot of grate.

"At this present time great exertions are being made to reduce both weight and space occupied by the boilers and coals. In a marine engine the amount of coal burned per square foot of grate is a measure of the efficiency of the machinery, for, no matter how economical the engines may be, if

the combustion is slow, a large amount of grate surface is necessary, and the consequent weight of the boiler excessive. Most of our American sea-going steamers have boilers designed to burn anthracite coal with natural draught, which gives from 5 to $5\frac{1}{2}$ horse-power per square foot of grate, while foreign vessels, using bituminous coal, obtain from 7 to 8 horse-power; and in some of the large Atlantic liners, using the best quality of Cardiff coal, as high as 10 horse-power per square foot of grate has been attained. We now learn that the English government designs increasing this performance by fitting air-tight fire-rooms to the merchant vessels recently purchased by them. The most successful use of artificial draught seems to be obtained by making the fire-rooms air-tight and providing blowers sufficient to maintain the air-pressure required.

"The air-supply is obtained from blowers receiving the air from the out-side and delivering it into the closed space of the fire-room. In some vessels it is so arranged that the ventilation of the hull is secured by the same blowers receiving the air through ducts from the holds, or living quarters of the vessel — a rather questionable arrangement, unless the blowers are of extraordinary capacity, and this on account of the difficulty of getting a sufficient supply of air to them. The average consumption of coal in a marine boiler will not exceed 12 lbs. of anthracite or 16 lbs. of bituminous coal per square foot of grate, which is raised to 18 or 20 by the use of the ordinary jet. But the large amount of steam used, compared with the gain in horse-power, makes the cost of an i. h. p. in coal excessive."

The following description of applications of forced draught on the closed ash-pit system, by

J. R. Fothergill, M. I. N. A., published in the "*Mechanical Engineer*," will without doubt be of interest to the reader, and will, as we hope, serve to convince him of the feasibility of our project. The description referred to being rather minute, we, therefore, do not give in the following the entire article, but only an abstract including those points, which will mainly serve to illustrate our idea.

"In September, 1884, the writer applied forced draught to the boiler of the s. s. '*Marmora*,' which ran with considerable success till she became a total wreck. The '*Marmora's*' boiler was built in 1874. The two bottom furnaces entered one combustion chamber, and it was not, therefore, a good subject for experiment. The engines of this steamer were compound direct-acting; cylinders, 25½ in. by 51½ in.; stroke 33 in., and 65 lbs. pressure; i. h. p. 400. Boiler: length 8 ft. 8½ in., diameter, 14 ft. 3 in.; four furnaces: length, 6 ft. 2 in., diameter, 3 ft. 1 in. Total heating surface, 1,700 sq. ft., including 283 3-in. tubes. The fan and engine were placed in a recess at the side of the boiler. The fan was driven by a belt, and the exhaust steam of the engine carried to the condenser of the main engines, or discharged into the waste steam pipe. Having no actual data to work upon, the arrangement fitted to the front of the boiler was specially designed to facilitate its ready removal should the experiment prove a failure. The fan was connected by a pipe to the square receiver running across the boiler front, to which was attached a lower receiver. From different points of these receivers connections were made to the closed ash-pits by short pipes, fitted with valves to regulate or shut off the supply of air to each or all of the fires, as might be required. From the ash-pits the air passed through

the dead-plates to the perforated baffles on the furnace fronts, and this supply of air was likewise regulated by a valve under the dead-plate.

"Before deciding the pressure at which the air should be maintained, consideration must be given to the particular work the ship is required to do. If it is a question of keeping down the weight, and getting speed regardless of consumption, such as required in the navy, a high pressure must be maintained. In the mercantile marine, especially with cargo steamers, economy is of the first importance, and thus we endeavor to evaporate the greatest quantity of water per pound of fuel consumed; whereas in the torpedo boat it is a question of evaporation, and not of wasted fuel. In the '*Marmora*,' we carried from $\frac{3}{8}$-in. to $\frac{5}{8}$-in. water gauge pressure in the ash-pits, depending on the condition of the fires, and the amount of clinker formed. This pressure allowed the air to enter with sufficient force through the perforations at the end of the ash-pits, and likewise through the baffles at the furnace fronts, thus maintaining a pressure in the furnace which a little more than balanced the ascending gases in the funnel.

From experience, the writer finds $\frac{3}{8}$-in. to $\frac{5}{8}$-in. water pressure gives the most economical results. With this pressure we do not unduly force the combustion, or cause a rapid delivery of the gases up the funnel at a high temperature with much loss of heat; in fact, we maintain a constant and regular draught equal to what is experienced with natural draught in a strong gale. As the air delivered under pressure penetrates up through the fuel, and enhances the combustion, it is necessary to reduce the grate surface, and use thicker fires. In the case of the '*Marmora*,' we shortened the fire bars 1 ft. 3 in., re-

ducing the total grate area 15.42 square ft., equal to 29.4 per cent., and increased the consumption per sq. ft. of grate per hour from 15.68 lbs. to 21.29 lbs. The amount of air delivered below the grate should be just sufficient to gasify the coal to carbonic oxide, and meet the requirements of the hydrogen in its conversion to steam. As the carbonic oxide is evolved, it should immediately take up another portion of oxygen from the air supplied at the furnace front or behind the bridge, and thus produce carbonic acid. The manner in which the delivery of the air takes place at the furnace front and behind the bridge, is of very great consequence, and it is advisable most strongly to draw attention to this in particular. If the air is admitted in a body or sheet, it cleaves its way through the gases, does not mingle with them, and produces a cooling effect; but, if the air is broken up, by passing through small holes, into innumerable jets, it, as it were, stirs up the gases, thoroughly mixes and combines with them, without reducing their temperature; producing the most effective result in the formation of carbonic acid. It will thus be seen how important it becomes to break the air up into jets before admission to the gases, for on this depends the quantity admitted, and thus the efficiency.

"In the '*Marmora*' we averaged about 18 lbs. of air per pound of coal consumed. In supplying forced draught to an ordinary boiler, or one not specially designed for such purpose, the velocity of the gases must be regulated by a damper in the funnel, otherwise the area through the tubes and of the funnel might be such that a pressure of air could not be maintained unless a very large quantity, much in excess of that required, was supplied. The damper should be placed in such position as

will maintain the air pressure, and allow the gases to escape in such quantity as will comply with the requirements of the air supply. In the '*Marmora*' the damper, half-closed, gave the best results. The actual result of the application of forced draught to the '*Marmora*,' based on a comparison of an average of eleven voyages under natural draught immediately prior to the application of forced draught, and eleven voyages with forced draught, which the steamer made before being wrecked, is as follows:—

SUMMARY RESULTS.

Condition.	Dist'ce in knots.	Days steaming.	Knots per hour.	Consumption p. day steaming.	Total cost of coal p. voyage. £ s. d.
Natural draught prior to alteration.....	3168	16.81	7.85	8.81	78 9 5
Forced draught after alteration.....	3102	16.74	7.72	8.58	44 12 10
Difference	66	.07	.13	.23	33 16 7

This table shows the consumption per day steaming. The distance, time, and speed per voyage were practically the same in each case; but there was a saving of 43 per cent. effected in the cost of the bunker coals per voyage, equal to £33, 16s., 7d. This saving was entirely due to the use of a cheap and inferior coal, which we were able to consume with forced draught to the same efficiency as a high class coal with natural draught. In striking the above averages, no allowance whatever has been made for bad weather, much experienced in this trade, nor for other incidents; but the data are entirely taken from the actual work done, as given in the log books. In the '*Marmora*' the air supply was drawn from the stoke hole, and its temperature ranged

from 70° F. to 90° F. In some systems of forced draught the air is made to circulate through tubes or passages, etc., which are heated by the waste gases as they pass to the funnel. There can be no question that each degree of heat so obtained and returned to the furnace must be a distinct gain, in that it saves reducing the furnace temperature by the amount of heat added to the incoming air.

"The specific heat of water is four times greater than that of air; therefore, if air were used instead of water for the ordinary purposes of condensation, we should require 3369 cub. ft. of air to do the same work as 1 cub. ft. of water, assuming the temperatures to be the same in each case, 62° F. Weight for weight, and other conditions the same, the capacity of water for heat is four times that of air. The question thus arises, could not the heat of the waste gases be utilized to better advantage in raising the temperature of the feed water?

"The saving effected in the '*Marmora*,' which, in round figures, may be stated at £350 per annum, decided us, when building the s. s. 'Stella' fitted with triple expansion engines, and having two large boilers of 140 lbs. pressure, to apply forced draught to the boilers. This steamer trades to India, and as the arrangements with the various coaling stations are to supply best Welsh coal, the economy to be sought in the application of forced draught must be in consuming a high class coal to greater evaporative efficiency, viz., for the same amount of water evaporated and steam produced, the coal consumption should be materially reduced.

"This steamer has just returned from an Indian voyage, her dead weight carrying capacity being 3800 tons, average speed 9¼ knots, on a consumption of 13.5 tons ordinary north country coals per

day steaming, which is certainly a most successful achievement, working out to 1.4 lbs. per i. h. p. The writer believes the '*Stella*' is the first instance of a triple expansion engine having the boilers fitted with forced draught, and also that the '*Marmora*' was the first instance in which forced draught on the closed ash-pit system was applied to a boiler which had been for some time in use under the ordinary conditions of natural draught, and ran the same for eleven continuous voyages with considerable success.''

USEFUL INFORMATION.

A gallon of fresh water weighs $8\frac{1}{3}$ lbs., and contains 231 cubic inches. A cubic foot of water weighs $62\frac{1}{2}$ lbs., and contains 1728 cubic inches or $7\frac{1}{2}$ gallons.

Each nominal horse-power of a boiler requires 1 cubic foot of feed-water per hour.

One square foot of grate will consume on an average 12 lbs. of coal per hour.

Consumption of fuel averages $7\frac{1}{2}$ lbs. of coal, or 15 lbs. of dry pine wood for every cubic foot of water evaporated.

At above rate, about fifty-two horse-power would consume in an ordinary good furnace about two tons of coal daily (or ten hours) and would require 520 cubic feet or 3900 gallons of water.

American Coal.

COAL.		Per cent. of ash.	Theoretical value.	
			In heat units.	In pounds of water evap.
KIND OF COAL.	STATE.			
Bureau Co.,	Illinois.	5.20	13.025	13.48
Mercer Co.,	"	5.60	13.123	13.58
Montauk Co.,	"	5.50	12.659	13.10
Block,	Indiana.	2.50	13.588	14.38
Caking,	"	5.66	14.146	14.64
Cannel,	"	6.00	13.097	13.56
Lignite,	Arkansas.	5.25	9.215	9.54
"	Colorado.	9.25	13.562	14.04
"	"	4.50	13.866	14.35
"	Texas.	4.50	12.962	13.41
"	Washington Terr.	3.40	11.551	11.96
Caking,	Kentucky.	2.75	14.391	14.89
Cannel,	"	2.00	15.198	16.76
"	"	14.80	13.360	13.84
Lignite,	"	7.00	9.326	9.65
Cumberland,	Maryland.	13.98	12.226	12.65
Cannel,	Pennsylvania.	15.02	13.143	13.60
Connellsville,	"	6.50	13.368	13.84
Semi-bituminous,	"	10.77	13.155	13.62
Stone's Gas,	"	5.00	14.021	14.51
Youghiogheny,	"	5.60	14.265	14.76
Brown,	"	9.50	12.324	12.75
Anthracite,	"	3.49	14.199	14.70
"	"	6.13	13.535	14.01
"	"	2.90	14.221	14.72
Petroleum,	"		20.746	21.47

The above Table of American Coal has been compiled from various sources.

Furnace Efficiency.

Every pound of fuel requires a given quantity of oxygen for its complete combustion, and thus a given quantity of air. This varies with different fuels, but, in every case, less air prevents complete combustion, and an *excess of air causes waste of heat*

to the amount required to heat it to the temperature of the escaping gas. With chimney draught the experiments of the United States Navy show that ordinary furnaces require about twice the theoretical amount of air to secure perfect combustion. Prof. Schwackhoffer of Vienna found in the boilers used in Europe an average excess of 70 per cent. of the total amount passing through the fire, or that over three times the theoretical amount was used. A series of analyses by Dr. Behr of the escaping gases from a Babcock & Wilcox boiler with a chimney draught showed an average excess of air equal to 48 per cent. of the whole quantity. A series of 12 tests made by same with artificial forced draught, gave an average excess of only 22 per cent. of the whole quantity, and in a few cases none at all, with only traces of carbonic oxide, showing perfect combustion. Different fuels require different furnaces. and no one furnace or grate bar is equally good for all fuel. The "National Electric Furnace," however, with artificial forced draught is equally good for all types of boilers and all kinds of fuel.

Temperature of Fire.

The following table from M. Pouillet will enable temperature to be judged by the appearance of the fire.

APPEARANCE.	TEMP. FAHR.	APPEARANCE.	TEMP. FAHR.
Red just visible	977°	Orange deep	2010°
" dull	1290°	" clear	2190°
" cherry dull	1470°	White heat	2370°
" " full	1650°	Bright "	2550°
" " clear	1830°	Dazzling heat	2730°

To determine Temperature by Fusion of Metals, etc.

SUBSTANCE.	TEMP. FAHR.	METAL.	TEMP. FAHR.	METAL.	TEMP. FAHR.
Tallow	92°	Bismuth	518°	Silver pure	1830°
Spermaceti	120°	Lead	630°	Gold Coin	2156°
Wax. White	154°	Zinc	793°	Iron Cast med.	2010°
Sulphur	239°	Antimony	810°	Steel	2550°
Tin	455°	Brass	1650°	Wrought Iron	2910°

Table of Relative Value of Non-Conductors from Experiments by Chas. E. Emery, Ph. D.

NON-CONDUCTOR.	VALUE.	NON-CONDUCTOR.	VALUE.
Wool Felt	1.000	Loam dry and open	.550
Mineral Wool No. 2	.832	Slacked Lime	.480
Do. with Tar	.715	Gashouse Carbon	.470
Sawdust	.680	Asbestos	.363
Mineral Wool No. 1	.676	Coal Ashes	.345
Charcoal	.632	Coke in lumps	.277
Pinewood across Fibre	.553	Air Space undivided	.136

"Mineral Wool," a fibrous material made from blast furnace slag, is a good protection, and is incombustible.

Firing of Sawdust and Shavings.

For the last twelve years or more, the writer had, as a manufacturer and steam user, adopted the mode of forcing the shavings from the woodworking surfacers into the furnace. The boiler used was of about 60 horse-power. The air was forced into the furnace with the planer shavings at a velocity of about 12 feet per second and at an average temperature of about 60° Fahr. The shavings were forced through a pipe 12 inches in diameter, above grate, into the combustion chamber. The pipe had a blast gate to regulate the air enough in order to maintain

a pressure in the furnace, which a little more than balanced the ascending gases in the funnel or chimney. When the surfacers were in operation and the planer shavings forced into the furnace, the heating space was filled with flame to the rear end, and thence through the flues of the boiler, water being evaporated during the time very rapidly. All that the fireman had to do was to keep the furnace doors closed and watch the water in the gauges of his boiler. The combustion in the furnace was complete, as no smoke was visible. The shavings were forced into the combustion chamber in a spray-like manner, and were caught into a blaze the moment they entered. The oxygen of the air so forced into the furnace along with the shavings gave full support to the combustion. The amount of shavings consumed by being thus forced into the furnace was about fifty per cent. less than the amount consumed, when the fireman had to throw them in with his shovel. The air entering through the open doors cools down the interior, and it is quite clear, that the heat of the fire can not be so intense, when the doors are open and fresh shavings thrown on top of the burning stuff, something that has to be done very frequently. Besides, the fireman, in most cases, throws into the furnace as many shavings as he can get in above grate. The result is that the necessary air can not pass through the mass of burning stuff, and it will thus be seen that nearly half is wasted by smothering the mass of fuel. But when the shavings are forced into the furnace, and the doors are kept closed, and the heating space is all ablaze, powerful heat is given to the boiler. The writer found this mode of firing better for the boiler, securing less labor and a saving in fuel where there are shavings to any amount.

Amount of Coal burned by Ocean Steamships.

Coal is a serious item in the expense of ocean-going steamships in these days of fast ships and quick passages. Two thousand dollars per day spent for fuel, is a sum exceeded by several of the swift transatlantic ships. It may be observed from the table following, what the actual average cost of fuel alone is for the largest vessels:

	COAL CONSUMED PER DAY. TONS.	AVERAGE KNOTS PER HOUR.	COST OF COAL PER VOYAGE.
Oregon	337	$17\frac{9}{10}$	$18.872
City of Rome	304	16	17.024
Alaska	253	$16\frac{8}{10}$	15.168
Servia	214	$16\frac{5}{10}$	11.956
Aurania	214	$16\frac{7}{10}$	11.056
America	182	$17\frac{3}{10}$	10.192
Austral	115	$16\frac{3}{10}$	6.440

The round trip expenses run from $40,000 to $70,000.

What an enormous waste in fuel must be taking place in the above cases! The amount of coal burned, as stated above, by the steamship Oregon, under skillful management, is 337 tons per day. Now if once and a half of the theoretical amount of atmospheric air used in combustion is 225 cubic feet, a volume equal to 18 pounds of air to every pound of coal, or 450,000 cubic feet of air to a ton of coal, 337 tons would require 151,650,000 cubic feet of atmospheric air. Of this vast volume, oxygen, which is the only combustible element in it, constitutes but one fifth, while the nitrogen, representing four fifths of the entire volume, is not only quite useless in combustion, but even retards it, and absorbs a large proportion of the heat of the fire. If we imagine the 151,650,000 cubic feet

of air made into a long stream of one square foot in area, the total length will be 28,722 miles. Of this vast stream 22,978 miles are useless nitrogen passing into the furnace cold and out of it hot.

Boiler Explosion.

(Abstract from the Works of John Bourne, C. E.)

There are many causes of boiler explosions.

The chief cause of boiler explosions is, undoubtedly, too great a pressure of steam, or an insufficient strength of boiler, generally resulting from oxidation; but many explosions have also arisen from the flues having been suffered to become red hot. If the safety valve of a boiler be accidentally jammed, or if the plates or stays be much worn by corrosion, while a high pressure of steam is nevertheless maintained, the boiler necessarily bursts; and if, from an insufficiency of water in the boiler, or from any other cause, the flues become highly heated, they may be forced down by the pressure of the steam, and a partial explosion may be the result. The worst explosion is where the shell of the boiler bursts; but the collapse of a furnace or flue is also very disastrous, generally to the persons in the engine room; and sometimes the shell bursts and the flues collapse at the same time; for if the flues get red hot, and water be thrown upon them either by the feed pump or otherwise, the generation of steam may be too rapid for the safety valve to permit its escape with sufficient facility, and the shell of the boiler may, in consequence, be rent asunder. Sometimes the iron of the flues becomes highly heated in consequence of the improper configuration of the parts, which, by retaining the steam in contact with the metal, prevents the access of the

water. The bottoms of large flues, upon which the flames beat down, are very liable to injury from this cause; and the iron of the flues thus acted upon may be so softened that the flues will collapse upwards with the pressure of the steam. It is found that a sudden disengagement of steam does not immediately follow the contact of water with the hot metal, for water thrown upon red hot iron is not immediately converted into steam, but assumes the spheroidal form and rolls about in globules over the surface. These globules, however high the temperature of the metal may be on which they are placed, never rise above the temperature of 205°, and give off but very little steam; but if the temperature of the metal be lowered, the water ceases to retain the spheroidal form, and comes into intimate contact with the metal, whereby a rapid disengagement of steam takes place.

One useful precaution against the explosion of boilers from too great an internal pressure, consists in the application of a steam gauge to each boiler, which will make the existence of any undue pressure in any of the boilers immediately visible; and every boiler should have a safety valve of its own, the passage leading to which should have no connection with the passage leading to any of the stop valves used to cut off the connection between the boilers, so that the action of the safety valve may be made independent of the action of the stop valve. In some cases stop valves have jammed, or have been carried from their seats into the mouth of the pipe communicating between them, or have not been opened, and the action of the safety valves should be rendered independent of all such accidents. Safety valves themselves sometimes stick fast from corrosion, from the spindles becoming bent, from a

distortion of the boiler top with a high pressure, in consequence of which the spindles become jammed in the guides, from a larger expansion of the brass seat than of the cast iron socket in which it is set, and from various other causes which it would be tedious to enumerate.

Proportions, Heating Surface, and Horse-Power of Boilers Fitted with Six Inch Flues.

HORSE-POWER AT 12 FEET.	BOILER SHELL.		NUMBER OF FLUES.	HEATING SURFACE, ⅔ SHELL, AND WHOLE OF FLUES.
	DIAMETER.	LENGTH.		
	Inches.	Feet.		Square Ft.
16.7	42	12	6	201
19.6		14	6	235
22.3		16	6	268
25.2		18	6	302
28.0		20	6	336
21.8	44	12	9	262
25.5		14	9	306
29.1		16	9	349
32.7		18	9	392
36.4		20	9	437
23.8	46	12	10	285
27.7		14	10	332
31.6		16	10	379
35.7		18	10	428
39.6		20	10	475
27.3	48	12	12	327
31.2		14	12	381
36.3		16	12	436
40.8		18	12	490
45.4		20	12	545
50.0		22	12	600
36.7	54	14	14	440
41.9		16	14	503
47.2		18	14	566
52.3		20	14	628
45.3	60	14	18	543
51.7		16	18	620
58.1		18	18	697
64.5		20	18	774
82.7	66	20	24	992

Proportions, Heating Surface, and Horse-Power of Boilers Fitted with Four Inch Tubes.

HORSE-POWER AT 15 FEET.	BOILER SHELL.		NUMBER OF TUBES.	HEATING SURFACE, ⅔ SHELL, AND WHOLE OF TUBES.
	DIAMETER.	LENGTH.		
	Inches.	Feet.		Square Ft.
28.5	48	12	26	428
33.2		14	26	498
38.0		16	26	570
42.7		18	26	641
47.5		20	26	713
32.1	50	12	30	482
37.5		14	30	562
42.9		16	30	643
48.1		18	30	722
53.5		20	30	803
34.1	52	12	32	511
39.7		14	32	596
45.4		16	32	681
51.1		18	32	766
56.8		20	32	852
37.7	54	12	36	565
44.0		14	36	660
50.3		16	36	754
56.6		18	36	849
62.8		20	36	942
42.1	56	12	41	632
49.2		14	41	738
56.2		16	41	843
63.3		18	41	949
70.3		20	41	1054
45.7	58	12	45	686
53.5		14	45	802
61.1		16	45	916
68.7		18	45	1030
76.3		20	45	1144
46.9	60	12	46	704
54.7		14	46	821
62.6		16	46	939
70.3		18	46	1055
78.1		20	46	1172
94.0	66	20	56	1410

The Prevention of Scale in Steam Boilers.

(From the Scientific American Suppl.)

The formation and prevention of scale in steam boilers has been, from time to time, discussed pretty keenly in almost every mechanical and engineering journal. The number of specifics and nostrums, sold under all kinds of fancy names, for its prevention and removal are legion. Complicated apparatuses and constructions have also been proposed, and, to some extent, used for removing the scale by boiling and heating the feed-water under pressure previous to use. Unfortunately, however, the trouble and expense of these arrangements, added to their first cost, come to nearly the same thing as simply replacing the worn out steam boiler, which has become injured by scale, with a new one.

Learned articles with chemical signs and equivalents have been published, explaining scientifically the theory and formation of boiler scale; but to many steam users unacquainted with chemistry, they are about as instructive as if they were written in a foreign language. Perhaps it may not, therefore, be out of place to explain, in as simple a manner as possible, the nature of boiler-scale and the cause of its formation. What is termed boiler-scale is a mineral deposit from the feed-water, whenever hard water is used as a source of supply. All lake, river, and spring water is more or less hard. The hardness is caused by the water coming in contact with certain mineral substances which the water dissolves to a small extent when running over or through the ground. These substances are chiefly carbonates and sulphates of lime, some magnesia,

and at times, traces of iron. There are two kinds of hard water, which chemists call "temporary" and "permanent" hard water. The first kind, or temporary hardness, is caused by the carbonate of lime and magnesia which has been dissolved by the water, and it is called temporarily hard because, when the water is boiled, all the carbonate of lime is rendered insoluble, that is to say, it is no longer dissolved by the water, but is thrown out, and falls in a white, slimy deposit of carbonate of lime.

The second kind of hard water, that termed permanently hard, is caused by the sulphate of lime dissolved by the water. Simple boiling does not make it insoluble or remove it. The water, therefore, that contains it, is permanently hard, that is to say, it can not be softened by simple boiling, but only by boiling under a high pressure, or by heating the water up to a high temperature, which means the same thing.

All water contains more or less of these two substances, carbonate and sulphate of lime, causing the temporary and permanent hardness. They are by no means always present in the same quantities or proportions, that is to say, some waters are much harder than others, and some are much more temporarily hard than permanently hard, or the reverse may be the case.

It will be seen, therefore, from this simple explanation that the carbonate and sulphate of lime must both be rendered insoluble and deposited in the steam boiler, the first as soon as the water begins to boil, the second as soon as the water comes under the steam pressure of the boiler. It will also be evident that they will be deposited in the hottest place in the steam boiler, that is to say, just on the surface of the plates exposed to the fire,

it being entirely the action of the heat that makes them insoluble. This is, of course, what takes place in practice. The coolest water in the boiler is constantly descending, the hot water ascending. The cold water is deprived of its lime salts just on the surface of the heated plate; the purified water passes up, bearing the sulphate and carbonate of lime sticking to the boiler plate in the form of scale. The action of this scale is that of a non-conductor, that is to say, it keeps the heat passing into the iron plate from being imparted to the water of the boiler; the consequence is a largely increased consumption of fuel, and the burning of the boiler-plate by the fire, owing to its not being in contact with the water, and thus kept cool.

From the above simple description of the theory of the formation of boiler-scale, it will be evident that if the substances causing the hardness of the water, and also the boiler-scale, can be rendered insoluble before they come in contact with the heated boiler plate, the formation of the boiler-scale will be impossible. This is all that is required, and not necessarily their removal previous to entering the boiler, as they settle down to the bottom, instead of adhering to the plates or the tubes, and pass away by the blow-off tap. This is, or rather should be, the object of the many boiler compounds sold as anti-crustators; but of the many different kinds offered to the public, few fulfill the necessary conditions of doing their work cheaply and effectively.

A boiler compound should, in the first place, render all the lime salts insoluble before they are rendered insoluble by coming in contact with the heated plates of the boiler. Secondly, it should have no action whatever on the iron of which the

boiler is made; and lastly, it should be cheap, readily obtained, and easy to handle.

Now, considering all these points, no substance seems better suited for the purpose than pure soda. The usual form, or what is generally understood by soda, is soda ash or soda crystals. These articles, however, are not soda properly so called, but carbonate of soda more or less impure, that is to say, soda in combination with carbonic acid, and in this form sluggish and comparatively ineffective in rendering insoluble and removing the carbonates and sulphates of lime which form the boiler-scale. Soda properly so called is "caustic soda," that is to say, soda uncombined with any acid, and, therefore, in a free state. This article is very effective in softening water, or in other words, rendering the carbonates and sulphates of lime insoluble, and when pure, has no action whatever on the boiler plates. When required for boiler purposes it should always, therefore, be used in a pure state, say not less than a strength of 98 per cent., the total impurities, therefore, not exceeding 2 per cent. Common caustic soda, as sold in drums containing large solid blocks, does not do well for boiler purposes; the usual strength of this article is only 60 per cent., and it contains sulphur salts, besides a large quantity of common salt, which acts very prejudiciously on the boiler plates. The pure 98 per cent. caustic soda is prepared in a powdered form by some manufacturers; and one of them, the Greenbank Alkali Co., of St. Helen's, England, seems to have made a specialty of it in small, air-tight 10 lb. canisters, which are very convenient for small consumers. With the powdered caustic soda there is no trouble in handling or weighing out the exact quantity required, as is the case with the large solid blocks in

drums, and it also dissolves instantly in cold water. In using pure, powdered caustic soda for boiler purposes, all that is necessary is to put a small quantity daily into the feed-water of the boiler. In this way the lime is all rendered insoluble, forms no scale, and passes off in the blow-off as a muddy sediment.

The quantity required is quite small, as a very little really pure caustic soda goes a long way. In ordinary cases about 3 lbs. added daily to the feed-water of a 20 horse-power boiler will keep it perfectly clean and free from scale. For large consumers, with many boilers, a more accurate estimation of the quantity required to soften the water will be necessary.

It has been already mentioned that ordinary water is of varying degrees of hardness and composition, but if drawn from the same source it is generally fairly uniform. The very hardest water generally met with will be softened and the lime removed by adding one-quarter of an ounce of pure, powdered 98 per cent. caustic soda to each gallon of water.

In most cases one-eighth part of an ounce is sufficient, and where the water is fairly good, one-sixteenth part of an ounce to the gallon of water will prevent all scale. To ascertain the quantity necessary, add one-sixteenth part of an ounce of 98 per cent. powdered caustic soda to a gallon of water and boil it, as this causes the lime sediment quickly to settle. Pour off the clear water and add to it another sixteenth part of an ounce of powdered caustic soda; if the water remains clear, the first addition of soda is sufficient to remove the lime salts. If it become muddy, the second quantity added is necessary. In this way a sufficiently accurate estimation of the quantity of pure powdered

caustic soda required can be made, and then added to the feed-water in the same porportion. For example, suppose one-sixteenth part of an ounce per gallon was necessary. This will be just about four pounds of powdered 98 per cent. caustic soda to the thousand gallons; and, as the cost of really pure powdered soda is about two pence per pound, the cost of perfectly softening the water will be eight pence per thousand gallons—a small cost compared with the advantage obtained of having no boiler-scale.

If the quantity of water used in the steam boiler can not be easily ascertained, and the water is to be softened by adding Greenbank's 98 per cent. powdered caustic soda, per 1000 gallons, used as given in the previous directions, the requisite quantity can be arrived at in the following manner:

Good Water. — One pound of Greenbank's 98 per cent. powdered caustic soda for each ton of coal burnt.

Medium Water. — Two pounds of Greenbank's 98 per cent. powdered caustic soda for each ton of coal burnt.

Hard Water. — Three pounds of Greenbank's 98 per cent. powdered caustic soda for each ton of coal burnt.

The Greenbank powdered caustic soda should be put daily into the feed water in the above proportions, and the blow-off tap used rather more frequently. All scale will in this manner be prevented. The Greenbank Double Concentrated 98 per cent. Powdered Caustic Soda being pure, has no action whatever on the boiler plates or fittings.

This is not the case with the ordinary caustic soda, owing to the impurities it contains, and which frequently has caused it to be justly condemned as a boiler anti-crustator.

Instructions to Engineers.

Rules for engineers and firemen for the management and care of steam boilers in getting up steam. —Before lighting the fire in the morning, raise your safety valve, and ascertain how many gauges of water there are in your boiler. Never unbank or replenish the fires until this is done. Accidents have occurred, and many boilers have been entirely ruined from neglect of this precaution. To guard against loss by leakage and evaporation, leave the water up to the third gauge at night and keep it up to the second gauge during working hours. Clean all ashes and cinders from the furnace and ash-pit, and spread a layer of two or three inches of coal over the grate bars; pile on plenty shavings over the coal, with dry sawdust, and split wood, etc., then start your fire. Keep the fire even and regular over the grate bars, about five inches thick with soft coal, and about three inches with anthracite, and always avoid excessive firing. Moderate charges, or firings, at intervals of 15 or 20 minutes, give the best result. In getting up steam from cold water, the fire should be raised gradually, to avoid damaging the boiler by unequal expansion of the iron. If steam commences to blow off at the safety valve, while the engine is at rest, start your pump or injector to create a circulation, cover or bank your fire with a charge of ashes or fresh coal to absorb the heat, and allow the steam to have free egress through the safety valve. If by neglect the water gets very low, and the boiler dangerously hot, the fire should either be drawn, or drenched with water. Should the fire be very hot, and the water supply temporarily cut off, stop the engine and cover the fire quite thickly with fresh fuel to absorb the heat,

keeping the usual allowance of water in the boiler until the supply is renewed. Boilers should be blown out every 2 or 3 weeks, or as often as mud appears in the water, but never until after the fire has been drawn at least one hour, and the damper closed, otherwise the empty boiler might be damaged by the heat. Never fill a hot boiler with cold water, as the sudden contraction many times repeated will eventually cause it to leak. Never blow out a boiler with a higher pressure than 50 lbs. to the square inch, as steam at a high pressure indicates a high temperature in the iron, which under careful management should always be let down gradually. Previous to filling a boiler, raise the valve to permit the free egress of air which might otherwise do manifold damage. Use every possible precaution against foul water, as it induces foaming in the boiler; soapy or oily substances and insufficiency of steam room have a like effect, causing a boiler to burn on the spots where the water is lifted from it, and the glass gauges to indicate falsely.

Keep gauge cocks clear and in constant use; glass gauges should not be relied on altogether.

Particular care should be taken to keep sheets and parts of boiler exposed to the fire perfectly clean.

Under all circumstances keep the gauges, cocks, etc., clean and in good order, and things generally in and about the engine and boiler room in a neat condition.

Keep a sharp lookout for leaks, and repair them if possible without delay, and allow no water to come in contact with the exterior of the boiler under any circumstances. Examine and repair every blister as soon as it appears, and make fre-

quent and thorough examination of the boiler with a small steel hammer.

In case of foaming, close the throttle, and keep it closed long enough to show true level of water. If the water level is right, feeding and blowing will generally stop the trouble. With muddy water it is a safe rule to blow out 6 or 8 inches every day. If foaming is violent from dirty water, or change from salt to fresh, or from fresh to salt, in addition to following the above directions, check draught, and cover the fire with ashes or fresh fuel.

Great watchfulness is necessary, when steam is raised, the safety valve fixed, the fire strong, and the engine at rest. In every case there is a rapid and dangerous absorption of heat, the temperature, latent and sensible heat included, often rising to 1200° Fahrenheit.

Frequently it is but the work of an instant to convert the latent into sensible heat, thus generating an irresistible force which bursts the boiler and destroys life and property. The destruction generally takes place at the moment of starting the engine, the opening of the valve inducing a commotion in the water, which flashes into steam the instant it strikes the heated plates. Steam has been known to rise from a pressure of 32 lbs. to the square inch to 90 lbs. to the square inch, in the short space of seven minutes, with the engine at rest. It ought to quicken the vigilance of every engineer to know that the explosive energy in each and every cubic foot of water in his boiler at 60 lbs. pressure, is equal to that contained in 1 lb. gunpowder.

Before starting the engine, warm the cylinder by admitting steam so as to slowly move the piston back and forth, letting the condensed water flow

from the drip-cocks, which should be left open all night for this purpose; especially should this be done during cold and frosty weather, during which time all pipes and connections should have extra protection.

The minimum speed of the piston should be 240 feet per minute, and the maximum speed 700 feet in any engine.

Employ Qualified Engineers.

From avaricious motives it has become quite common to discharge or to decline to employ qualified and careful engineers.

Incompetent men are employed, because their labor costs a few dollars less than that of the former. This is too much of a bad thing to pass over without notice. Employ good skillful men in the management of steam power, and pay them decent wages or employ none at all.

If an oversight takes place, and the best and most careful men are liable to make mistakes, never scold, reprimand, or exact service during dangerous emergencies, as in the event of lost water in the boiler. In no case risk life, limb, or property, and do not let the consideration of saving a few dollars debar you from securing intelligent assistants.

The Turkish mode of driving business on a late occasion was to discharge the English engineers who brought the war vessels which were built in England, and supply the vacancies by installing cheap green hands. After getting up steam the new "Chief" proceeded to start the engines. A lift at a crank produced no results, a pull at a lever was

equally useless. At length the illustrious official espied a bright brass cock, and thinking he had got hold of a sure thing this time, proceeded to give it a twist, when he was suddenly saluted with a jet of steam full in the face, which swept the "engineer" and his assistants out of the engine room, into the fire room down stairs.—So much for cheap labor and the consequent results.—*M. A. Guide.*

New Boilers and Engines.

In starting new machinery for the first time, the greatest care should be taken, in order to prevent injury. The change from low temperature to very high ones exerts tremendous force, which is all the more dangerous and insidious for the reason that its effects are not seen until the mischief is done. This great force is expansion, or the dilation of volume—bulk, or superfices, by heat, and those unfamiliar with it, have no conception of the strains set up. We shall not go into a discussion of them in this article, for it would require many figures and references to authorities and physics for which the general reader has little interest. We content ourselves with brief practical directions for avoiding damage to plant, involving future repair and pecuniary loss.

Boilers newly set should be heated very slowly indeed, and the fires should not be lighted under the boilers for at least two weeks after setting, if it is possible to wait this length of time. These two weeks enable all parts of the mason work to set gradually and harden naturally; the walls will be much more likely to remain perfect, than where fires are lighted, while the mortar is yet green.

When a fire is started under a new boiler for the first time, it should be a very small one, and no attempt should be made to do more than moderately warm all parts of the brick work. A slow fire should be kept up for twenty-four hours, and on the second day it may be slightly increased. Three full days should elapse before the boiler is allowed to make any steam at all.

When the pressure rises it should not be allowed to go above four or five pounds by the gauge, and the safety valve weight should be taken off to prevent any possibility of increase. Steam should be allowed to go through all the pipes attached for steam, and blow through the engine before any attempt is made to get pressure on them. The object of all these precautions and this care is to prevent injury by sudden expansion, which, as we have already stated, may cause great damage. The cylinder itself should be thoroughly heated before the engine is started, and the back head should be left off and steam blown through the port by moving the valve by hand. This will drive out any borings or chips and core sand left in the parts. If these precautions are observed, and the engine run very slowly indeed, at first, for a few hours, increasing the speed by degrees, the probabilities are that much fewer repairs will be needed than where reckless haste is used to start up at once after the last joint has been made on the premises.—*Milling Engineer.*

Practical Remarks on Combustion and Firing of Steam Boilers.

Carbon is the chief constituent of anthracite and bituminous coals. Anthracite contains only about 4 per cent. of hydrogen, and when burning produces

but little flame or smoke. Bituminous coal contains more hydrogen, and it is this gas which produces flame during its combustion. Bituminous coal being a combination of hydrogen and carbon, when in its natural state, is classed with hydrocarbons, whereas, hard coal is considered as almost pure carbon; chemically it is an impure sub-variety of it. Gas-coke resembles anthracite, minus its small amount of volatile gases.

The solid and liquid fuels which the bowels of the earth contain, were probably formed at a very early period, as their presence has been known for centuries. When anthracite was first discovered, it was thought to be a useless substance of no commercial value. The heat value of a pound of Pennsylvania anthracite is about 14,198 units; by some it is given as 14,500. There is a lignite coal mined in Kentucky and Arkansas, the heat value of which is not above 9300, while the heat value of dry wood is not above 5600. The object of this article is not to dilate on the value of different kinds of fuel, but rather, to draw attention to the combustion of it.

In the furnace much of the gaseous portion of the fuel is lost by improper handling of the fires, and by too much or too little air being admitted through or above the grate bars.

Some have been led to believe that it is advantageous to wet bituminous coal preparatory to putting it upon the fire, but there can be no economy in burning wet fuel of any kind, for much of the available heat of the fuel is rendered latent in the steam and other vapors liberated from the wet fuel by the heat of the furnace, and the heat so absorbed is given out again only after the gases are condensed outside, or within the chimney.

When a furnace is first charged with wet tan or green wood, we observe dense clouds of smoke and steam escaping from the chimney-top, and after a few hours' run, if we should then examine the flues or tubes, would find them coated with soot, which is a sure indication of imperfect combustion. I do not mean by this that the absence of smoke indicates that a furnace is consuming its own gases, for the waste of heat is sometimes enormous when no smoke is visible. For instance: I partly open the furnace doors soon after charging the furnace with fresh fuel. No vestige of smoke can be seen, but we know that the excess of air rushing in through the open doors, is cooling down and condensing the gases as they rise from the burning fuel, and carrying them off at a comparatively low temperature. Anthracite dust is unfit to burn dry, unless mixed with bituminous coal. The dust, when used alone, closes the air inlets through the grate-bars, cuts off the supply of oxygen necessary for combustion, and smothers the fire. Anthracite dust lies heavily on the grate-bars, like so much red hot sand, and if we disturb it with the fire tools, a large amount of the half-burnt fuel falls through the grate-bars into the ash-pit.—*M. Eng.*

Coal Tar Product.

One ton of ordinary gas coal will produce 10.008 cubic feet of gas, 20 or 30 gallons of Ammonia water—say 30—, 12 gallons or 140 lbs. of coal tar, and about three quarters of a ton of coke.

Valuable Information for Business Men.

Demand Notes are payable on presentation, without grace, and bear legal interest after a demand has been made, if not so written. An endorser on a demand note is holden only for a limited time variable in different states.

A Negotiable Note must be made payable either to bearer, or be properly endorsed by the person to whose order it is made. If the endorser wishes to avoid responsibility, he can endorse "without recourse."

A Joint Note is one signed by two or more persons, who can each become liable for the whole amount.

Three Days' Grace are allowed on all time notes, after the time for payment expires; if not then paid, the endorser, if any, should be legally notified, to be holden.

Notes Falling Due Sunday, or on a legal holiday, must be paid the day previous.

Notes dated Sunday are void.

Altering a Note in any manner, by the holder, makes it void.

Notes given by Minors are void.

The Maker of a Note that is lost or stolen is not released from payment if the amount and consideration can be proven.

Notes Obtained by Fraud or given by intoxicated persons, can not be collected.

An Endorser has a right of action against all whose names were previously on a note endorsed by him.

One Dollar Loaned 100 Years at Compound Interest would amount to the following Sum:

1	per cent.	$ 2.75	12	per cent.	$ 84,675.00
3	"	19.25	15	"	1,174,405.00
6	"	340.00	18	"	15,145,207.00
10	"	13,809.00	24	"	2,551,799,404.00

Greatest known Depth of the Ocean.

The greatest depth which has been ascertained by sounding is five miles and a quarter (25,720 feet or 4,620 fathoms), not quite equal to the height of the highest known mountain, Mount Everest, which measures 29,002 feet or $5\frac{1}{2}$ miles in height. The average depth between 60 degrees north and 60 degrees south, is nearly three miles.

First Steamboat and Locomotive in the U. S.

The first steamboat plied the Hudson in 1807. The first use of a locomotive in the United States was in 1829.

Long Measure—Distance.

3 barley corns 1 inch, 12 inches 1 foot, 3 feet 1 yard, $5\frac{1}{2}$ yards 1 rod, 40 rods 1 furlong, 8 furlongs 1 mile.

Lightning Rods.

The golden rule of safety is to provide the building with plenty of rods or conductors, and make sure that their lower ends, in the ground, are soldered to a large surface of metal or other conducting material placed underground. The common method is simply to stick the end of the rod three

feet down into dry earth. But this is unsafe, because dry earth is a very poor conductor of electricity. To compensate for this lack of conductivity, the bottom of the rod should communicate with a large extent of conducting material. This may be done by soldering the lower end of the rod to water or gas pipes, if they exist; if not, then dig a trench four feet deep, six inches wide at bottom, in which deposit a layer six inches thick of coal dust, charcoal, anthracite, or bituminous coal. Bed the end of the rod for several feet in this layer of coal, which is a pretty good conductor of electricity. The trench should be one hundred or more feet in length. The rods should be placed on all ridges, corners, and chimneys. All metallic roofs, gutters, and water-pipes should have soldered connection with the rod, which should not be insulated from the building. All metallic water, gas, stove, and other pipes within the building, all bell wires, masses of metal, machinery, should be connected with the ground, in the manner described for the rods. The more conductors that are connected with the ground in this way, the greater the safety.

Common one-half inch square iron makes a good conductor. So does copper wire one eighth inch in diameter.

Scraps of Information.

1. *The light from the sun* occupies $8\frac{1}{4}$ minutes in traveling the earth, the distance being ninety-two millions of miles. The light of the fixed star "Sirius," supposed to be the nearest of the stars, is $3\frac{1}{4}$ years in reaching the earth, the distance being over twenty millions of miles.

2. *The intensity of illumination* on a given surface is inversely as the square of its distance from the source of light. If the page of a book held twelve inches from a candle be moved six inches nearer, the light on the page is made four times stronger.

3. *Doubling the diameter* of a pipe increases its capacity four times. Friction of liquids in pipes increases as the square of the velocity. In calculating horse-power of Tubular or Flue boilers consider 16 square feet of heating surface equivalent to one nominal horse-power.

4. *Steam is a perfect gas* and follows the laws governing such fluids. It is stated that steam superheated in an independent vessel increases in pressure for every degree of increase in temperature. Also, that steam can not be superheated in the vessel in which it is generated. We respectfully dissent from both of these propositions; broadly upon the ground that it is a poor conductor of heat, and therefore, through want of circulation, various temperatures may exist in the same vessel.

Saturated steam of thirty pounds per square inch may increase in pressure when heated higher than its normal temperature, but dry steam will, we think, be an exception.—*M. Eng.*

Capacity of Cisterns for Each Ten Inches in Depth.

Twenty-five feet in diameter hold 3059 gallons.
Twenty feet in diameter hold 1958 gallons.
Fifteen feet in diameter hold 1101 gallons.
Fourteen feet in diameter hold 959 gallons.
Thirteen feet in diameter hold 827 gallons.
Twelve feet in diameter hold 705 gallons.

Eleven feet in diameter hold 592 gallons.
Ten feet in diameter hold 489 gallons.
Nine feet in diameter hold 396 gallons.
Eight feet in diameter hold 313 gallons.
Seven feet in diameter hold 239 gallons.
Six and one half feet in diameter hold 206 gallons.
Six feet in diameter hold 176 gallons.
Five feet in diameter hold 122 gallons.
Four and one half feet in diameter hold 99 gallons.
Four feet in diameter hold 78 gallons.
Three feet in diameter hold 44 gallons.
Two and one half feet in diameter hold 30 gallons.
Two feet in diameter hold 19 gallons.

Velocity and Force of the Wind.

DESCRIPTION OF THE WIND.	MILES PER HOUR.	FEET PER MINUTE.	PRESSURE ON A SQUARE FOOT IN POUNDS.
Barely observable	1	88	.005
Just perceptible	2	176	.02
	3	264	.045
Light breeze	4	352	.08
Gentle pleasant wind	5	440	.125
	6	528	.18
	8	704	.32
Fresh breeze	10	880	.5
Brisk blow	15	1320	1.125
Stiff breeze	20	1760	2.
Very brisk	25	2200	3.125
High wind	30	2640	4.5
	35	3080	6.125
Very high wind	40	3520	8.
Gale	45	3960	10.125
Storm	50	4400	12.5
Great storm	60	5280	18.
Hurricane	80	7040	32.
Tornado	100	8800	50.

Distinguished American Inventors.

Benjamin Franklin; b. Boston, 1706; d. 1790; inventor of the lightning-rod.

Eli Whitney; b. Westborough, Mass., 1765; d. 1825; inventor of the cotton gin.

Robert Fulton; b. Little Britain, Pa., 1765; d. 1825; inventor of the steamboat.

Jethro Wood; b. White Creek, N. Y., 1774; d. 1834; inventor of the modern cast-iron plough.

Thomas Blanchard; b. Sutton, Mass., 1788; d. 1864; inventor of tack machine.

Cyrus H. McCormick; b. Walnut Grove, Va., 1809; inventor of harvesting machines.

Charles Goodyear; b. New Haven, Conn., 1800; inventor of the simple mixture of rubber and sulphur.

Samuel F. B. Morse; b. Charlestown, Mass., 1791; d. 1872; inventor of electric telegraph.

Elias Howe; b. Spencer, Mass., 1819; d. 1867; inventor of the modern sewing machine.

James B. Eads; b. Lawrenceburgh, Ind., 1820; d. March 8, 1887; author and constructor of the great steel bridge over the Mississippi at St. Louis, 1876, and the jetties below New Orleans, 1876. His remarkable energy was shown in 1861, when he built and delivered complete to Government, all within sixty-five days, seven iron-plated steamers, 600 tons each; subsequently, other steamers. Some of the most brilliant successes of the Union arms were due to his extraordinary rapidity in constructing these vessels.

The Great Wonders of America.

Yosemite Valley, California; 57 miles from Coulterville. A valley from 8 to 10 miles long, and about one mile wide. Has very steep slopes about 3,500 ft. high; has a perpendicular precipice 3,089 ft. high; a rock almost perpendicular, 3,270 ft. high; and waterfalls from 700 to 1000 ft.

Niagara Falls—A sheet of water three quarters of a mile wide, with a fall of 175 ft.

Natural Bridge over Cedar Creek in Virginia.

New State Capitol at Albany, N. Y.

Mammoth Cave in Kentucky.

New York and Brooklyn Bridge.

Croton Aqueduct in New York City.

Lake Superior—The largest lake in the world.

Washington Monument, Washington, D. C., 555 ft. high.

City Park, Philadelphia, Pa.—The largest park in the world.

The *Central Park* in New York City.

Height of Principal Monuments and Towers.

Names.	Places.	Feet.
Pyramid of Cheops,	Egypt,	486.
Antwerp Cathedral,	Belgium,	476.
Strasburg Cathedral,	Germany,	474.
Pyramid of Cephrenes,	Egypt,	456.
St. Peter's Church,	Rome,	448.
St. Martin's Church at Landshut,	Germany,	411.
St. Paul's Church, London,	England,	365.
Salisbury Cathedral,	England,	400.
Cathedral at Florence,	Italy,	387.
Cathedral at Cremona,	Lombardy,	396.
Church at Fribourg,	Germany,	386.

Names.	Places.	Feet.
Cathedral of Seville,	Spain,	360.
Cathedral of Milan,	Lombardy,	355.
Cathedral of Utrecht,	Holland,	356.
Pyramid of Sekkarah,	Egypt,	356.
Cathedral of Notre Dame,	Munich, Bavaria,	348.
St. Mark's Church,	Venice,	328.
Assinelli Tower, Bologna,	Italy,	272.
Trinity Church,	New York,	284.
Column at Delhi,	Hindostan,	262.
Porcelain Tower, Nankin,	China,	260.
Church of Notre Dame,	Paris,	224.
Bunker Hill Monument,	Massachusetts,	221.
Leaning Tower of Pisa,	Italy,	179.
Washington Monument,	Baltimore,	175.
Monument, Place Vendome,	Paris,	153.
Trajan's Pillar, Rome,	Italy,	151.
Obelisk of Luxor, now in	Paris,	110.

Highest and Greatest Mountains in the World.

Aetna, a volcano in Sicily, 10,900 ft.

Antisana, Republic of Ecuador, 14,300 ft.

Ararat, resting-place of Noah's Ark, Armenia, 12,700 ft.

Ben Nevis, highest in Great Britain, Scotland, 4,400 ft.

Black Mountains, the highest of the Blue Ridge, N. C., 6,500 ft.

Brown Mountain, highest of the Rocky Mountains, U. S., 16,000 ft.

Chimborazo, Republic of Ecuador, 21,400 ft.

Cotopaxi, the highest volcano, Ecuador, 18,900 ft.

Dhawalaghiri, one of the Himalaya Mountains, Asia, 25,500 ft.

Fremont's Peak, Rocky Mountains, Wyoming, 13,575 ft.

Geesh, highest in Africa, 15,100 ft.

Hecla, a volcano in Iceland, 5,500 ft.

Hindoo-Koosh, Afghanistan, 20,594 ft.

Jungfrau, Alps, Switzerland, 13,700 ft.

Lebanon, Syria, 10,000 ft.

Mansfield, highest of Green Mountains, Vermont, 4,275 ft.

Miltzin, highest of Atlas Mountain, Morocco, 11,498 ft.

Mont Blanc, Switzerland, 15,900 ft.

Mt. Everest, Himalayas, highest in the world, Thibet, 29,000 ft.

Mt. Fairweather, Alaska, 14,475 ft.

Mt. Hood, Oregon, 11,220 ft.

Mt. Marcy, highest in New York, 5,400 ft.

Mt. Ramier, Washington Territory, 14,445 ft.

Mt. Roa, highest in Oceanica, Hawaii, 17,500 ft.

Mt. Shasta, California, 14,440 ft.

Mt. Sinai, Arabia, 8,200 ft.

Mt. St. Helens, Washington Territory, 13,475 ft.

Mt. Washington, highest of White Mountains, N. H., 6,293 ft.

Mt. Whitney, California, 14,885 ft.

Olympus, Greece, 6,600 ft.

Ophir, Sumatra, East Indies, 13,800 ft.

Parnassus, the home of the Muses, Greece, 6,000 ft.

Peaks of Otte, Virginia, 4,250 ft.

Perdu Mount, highest of the Pyrenees, France, 11,300 ft.

Pike's Peak, Colorado, 14,215 ft.

Popocatapetl, highest in Mexico, 17,700 ft.

Round Top, highest of Catskill Mountains, N. Y., 3,800 ft.

Sneehatan, highest of the Doverfield Mountains, Norway, 8,110 ft.

Sorata, highest in Bolivia, S. A., 25,400 ft.

St. Bernard, Switzerland, 8,000 ft.

St. Elias, highest in North America, Alaska, 17,900 ft.

Stromboli, volcano in Mediterranean Sea, 3,000 ft.

Teneriffe, Peak of, one of the Canary Isles, 12,000 ft.

Vesuvius, volcano, near Naples, 3,900 ft.

The Longest and Greatest Rivers in the World.

Name.	Miles.	Name.	Miles.
Amazon	3600	Nebraska	1200
Nile	3000	Red River	1200
Missouri, to its Junction with the Mississippi,	2900	Colorado in Cal.	1100
		Yellow Stone	1000
		Ohio	950
Missouri, to the sea, the longest in the world,	4100	Rhine	950
		Kansas	900
		Tennessee	800
Mississippi, proper	2800	Red River of the North	700
Lena	2600	Cumberland	600
Niger, or Jobila	2600	Alabama	600
Obe	2500	Susquehanna	500
St. Lawrence	2200	Potomac	500
Madeira	2000	James	500
Arkansas	2000	Connecticut	450
Volga	2000	Delaware	400
Rio Grande	1800	Hudson	350
Danube	1600	Kenebec	300
St. Francisco	1300	Thames	233
Columbia	1200		

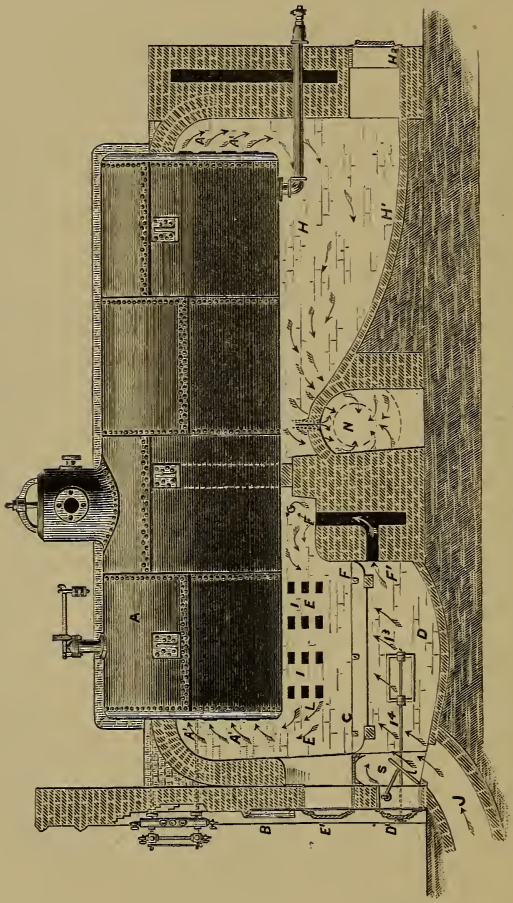
Number of Miles by Water from New York to

Amsterdam	3510	Kingston	1640
Bermudas	660	Lima	11310
Bombay	11574	Liverpool	3210
Boston	310	London	3375
Buenos Ayres	7110	Madras	11850
Calcutta	12425	Naples	4330
Canton	13900	New Orleans	2045
Cape Horn	8115	Panama	2358
Cape of Good Hope	6830	Pekin	15325
Charleston	750	Philadelphia	240
Columbia River	15965	Quebec	1400
Constantinople	5140	Rio Janeiro	3840
Dublin	3225	Round the Globe	25000
Gibraltar	3300	Sandwich Island	15300
Halifax	612	San Francisco	5858
Hamburg	3775	St. Petersburg	4420
Havana	1420	Valparaiso	9750
Havre	3210	Washington	400

Years of Age which various Animals attain.

Whale	1000	Cow	20
Elephant	400	Bear	20
Swan	300	Deer	20
Tortoise	100	Pigs	20
Eagle	100	Cat	15
Raven	100	Fox	15
Camel	100	Dog	20
Lion	70	Sheep	10
Porpoise	30	Rabbit	7
Horse	25 to 30	Squirrel	8

NATIONAL ELECTRIC FURNACE.

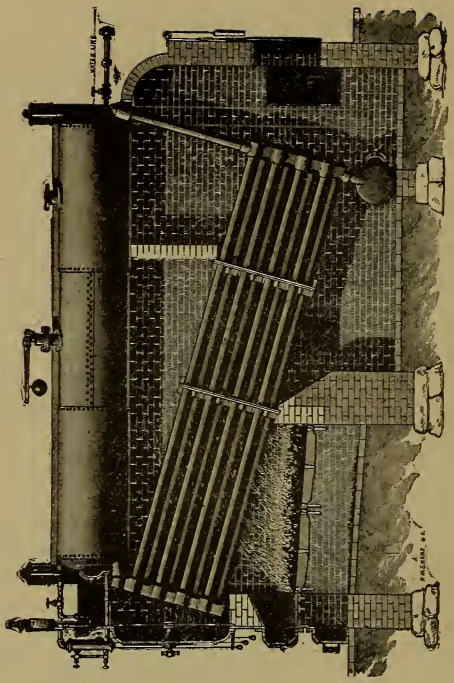


LONGITUDINAL SECTION.

Boilers of Various Types.

The *National Electric Furnace* is equally good for all constructed types of boilers. The construction of boilers has but very little effect on combustion. All that is required in a furnace is, that it must be so arranged, that the combustibles, heat, etc., are applied to all the heating surface to do the most work. In all furnaces, when fire is built upon the grate, it is necessary with natural draught to mix the air with the gases as close to the fire as possible, in order that the mixture may have sufficient heat to allow of burning, but, if the gases are allowed to escape or disengage and the disengaged carbon is cooled below the temperature of ignition, before coming into contact with oxygen, it constitutes, while floating in gas, smoke. The chilling of the gaseous hydro-carbons, which are driven off from the solid pieces of coal by the heat developed, may take place in two ways: either by finding too much cold air in the furnace, or by coming into contact with a cold body, as the iron of the boiler, the temperature of which at 75 lbs. pressure steam is 320 ° Fahr.; hence, the heated plates of the boiler, or the iron water tubes are below 400 ° Fahr. Thus it will be seen that the combustion takes place at the seat of fire, where the carbon of the coals, and the oxygen of the air have combined.

The arrangement in the *National Electric Furnace* can be mechanically regulated, so that the flames, heat, etc., be of a greater intensity or higher temperature, and denser or more compressed in the hot air space, enough for maintaining a pressure in the furnace which should a little more than balance the suction of the mixing apparatus and the ascending unconsumed and incombustible air in the chimney.

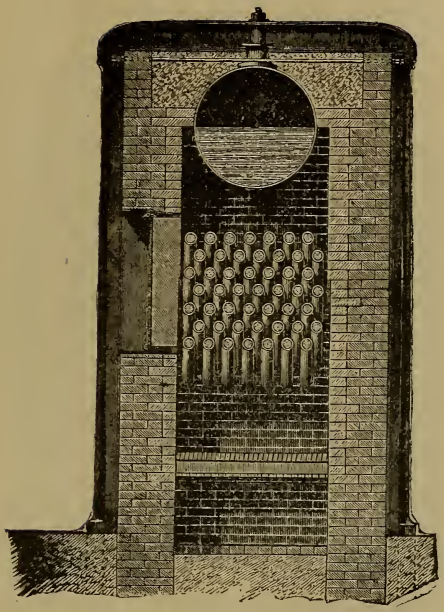


BABCOCK & WILCOX BOILER.

We will hereinafter give an illustration of a few different types of boilers.

There are many varieties of boilers in all shapes and forms; however, our aim is not to discuss any particular type, but to illustrate them to the reader. Of the many varieties of the water-tube type we select as an example one from the circular of the *Babcock & Wilcox Co.* The boiler consists of inclined sets of tubes connected at each end by steel

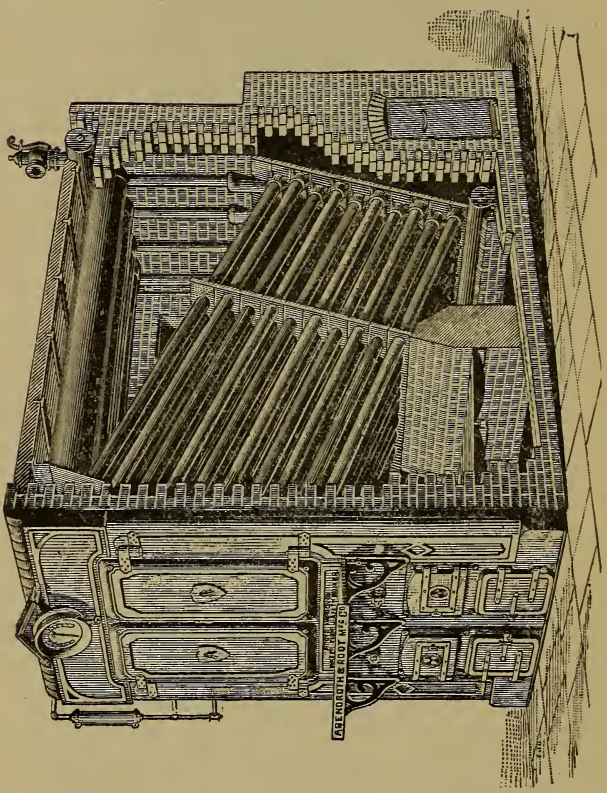
BABCOCK & WILCOX BOILER.



VERTICAL SECTION.

castings into which the tubes are expanded; the front and upper ends are connected into a longitudinal drum. The rear ends are connected by inclined pipes to the same drum, while at the bottom, there is a mud drum of cast iron. There are hand holes opposite each end of each tube and man heads on the steam and mud drums. The hand holes plates are milled to metal contact with the connections and the whole section is hung from overhead

ROOT'S NEW SAFETY BOILER.



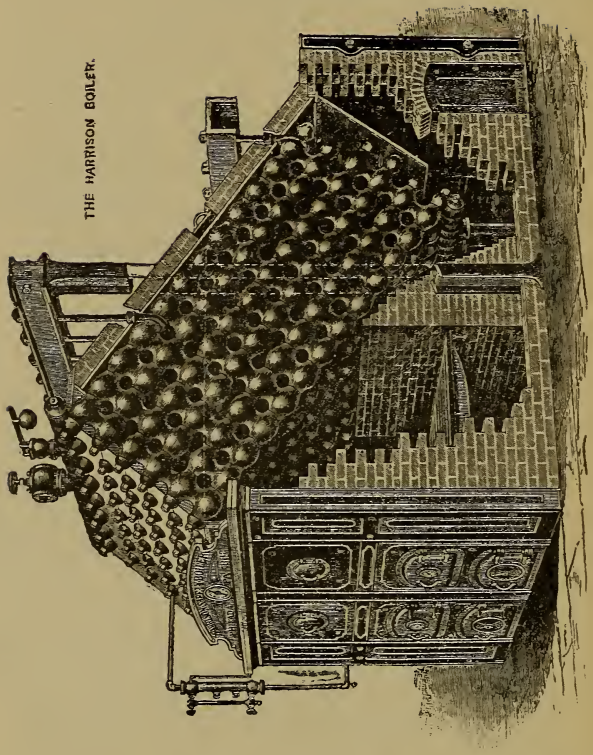
by bolts carried on cross beams resting on the walls. The heating surface of the water tubes are all exposed (or laying bare). The products of combustion are carried three times across the tubes by means of deflectors and those from all the different batteries are carried through the pipes of an "economizer," or feed-heater, on their way to the stack.

In *Heine's* boiler the connections at the front and back ends of the tubes are flat-stayed wrought iron plates, the stay bolts are made hollow and plugged; by taking out the plugs the outside of the water tubes may be cleaned. There are hand holes and plates opposite each end of each tube. The inclination of the tubes is not so great as in the other boiler. The product of combustion is carried backwards and forwards between and over the water tubes by means of having two layers of fire-brick tiles covered over the tubes about three-fourth the length.

Root's New Safety Boiler.

In this view a general arrangement of grate and heating surface and front of a 100 H. P. Boiler is shown. The feed water entering the mud drum at the rear and lower end of tubes is distributed through the heaters and thence passes through all the 4 inch tubes, forward and upward, until it enters the 14 inch tubes at the front end. In the 14 inch tubes the steam is separated from the water and thoroughly dried while passing along to the cross steam drum at the rear, while the water flows through the down takes and re-enters the tubes thus completing the circulation. The front ends of the tubes rest upon the heavy bearing beam attached to the front, while the rear and lower ends of the tubes rest on the cross mud drum.

HARRISON BOILER.



This arrangement permits the tubes lying in a staggered position, which insures a thorough mixture of the products of combustion, as well as absorption of heat. The flame passes at right angles across the front end of the 4 inch tubes around the 14 inch

tubes, thence across the lower end of the 4 inch tubes and out through the smoke flue of the chimney. In case of accident to a tube, all that is necessary to remove it, is to take off two heads at the rear and the corresponding bends at the front, remove the lock plate at the rear, then push the pair of tubes, containing the injured one to the front and thus out.

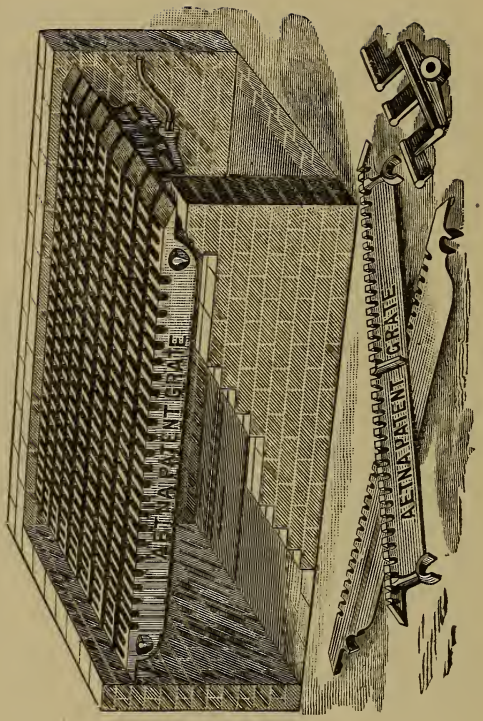
Harrison Boiler.

The most prominent among all them being the Harrison, which is made of cast iron globes united in straight lines by nicks, flanges and bolts. Each line of globes is thus a straight tube with alternate enlargements and contractions, and the boiler is subject to the incidentals of all the others of the tubulous class. The joints are, of course, much more numerous than with wrought-iron tubes, but they are claimed to be easier to make and to remain in better order. A great number of these boilers have been in satisfactory use in the eastern part of the United States and elsewhere.

From a Circular.

The Aetna Grate.

The Aetna Grate is a practicable and thoroughly successful shaking Grate Bar, simple in construction, positive and effectual in its operations easily worked (being operated in sections in wide furnaces), gives over 60 per cent. air space. Very durable, interchangeable, and can be put in *any furnace* without delay or change of any kind.



THE AETNA GRATE.

Description.

Upon the ordinary bearing bars are laid two or more, (according to width of furnace) stationary bars, suspended between these in openings near either end, are placed two rockers, which swing freely like a scale bearing upon pivot edges; upon these rockers are placed the moving bars. When at rest they present the same level appear-

ance as the ordinary grate. Attached to the front rocker is an extension socket, reaching almost to the ash-pit door; a lever put in this socket and worked imparts to the bars at the same instant a vertical and horizontal movement. By this action the under surface of the fire is thoroughly cleaned and opened. This condition can be maintained continuously with one or two moves of the lever, which is easily operated with one hand.

Grates.

For small furnaces the grates are usually rigid bars; and the fire is cleaned first by running a poker between them. In larger furnaces the grates are made to shake or rock, although the former is preferable.

What is the difference between a shaker and a rocker grate? The shaker has merely a horizontal movement to and fro, while the rocker turns on a pivot and has a vertical motion. Why is a shaker preferable? Because, an anthracite coal-fire beds down and becomes very compact, and is not seriously disturbed by shaking; whereas rocking lifts the coals from each other and it takes some time for them to readjust themselves and burn as before.

Eng. Catm.

Priming in Steamboiler.

What is priming?

Priming is a violent agitation of the water within the boiler, in consequence of which a large quantity of water passes off with the steam in the shape of froth or spray. Such a result is injurious, both as regards the efficacy of the engine and the safety

of the engine and boiler; for the large volume of hot water carried over by the steam in condensing-engines impairs the vacuum, and throws a great load on the air-pump, which diminishes the speed and available power of the engine; and the existance of water within the cylinder, unless there be safety valves upon the cylinder to permit its escape, will very probably cause some part of the machinery to break, by suddenly arresting the motion of the piston when it meets the surface of the water, — the slide valve being closed to the condenser before the termination of the stroke in all engines with lap upon the valve, so that the water within the cylinder is prevented from escaping in that direction if the slide valve be of the kind which will not leave its face. At the same time the boiler is emptied of its water too rapidly for the feed pump to be able to maintain the supply, and the tubes are in danger of being burnt from a deficiency of water above them.

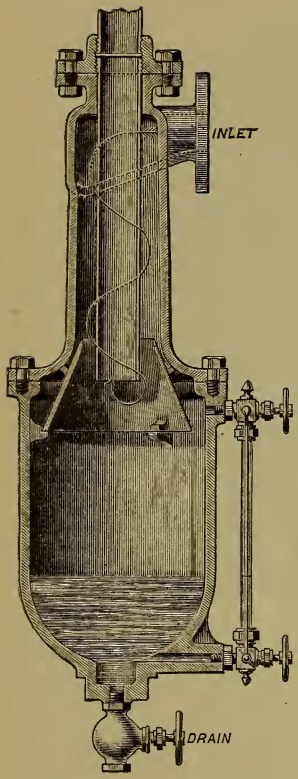
What are the causes of priming?

The causes of priming are an insufficient amount of steam room.

What is the proper remedy for priming?

When a boiler primes, the engineer generally closes the throttle valve, partially turns off the injection water, if a condensing engine operating by jet, and opens the furnace doors, whereby the generation of steam is checked, and a less violent ebullition in the boiler suffices. Where the priming arises from an insufficient amount of steam room, it may be mitigated by putting a higher pressure upon the boiler and working more expansively, or by interposition of a *Separator*, between the boiler and the steam chest.

Dry Steam Separator.

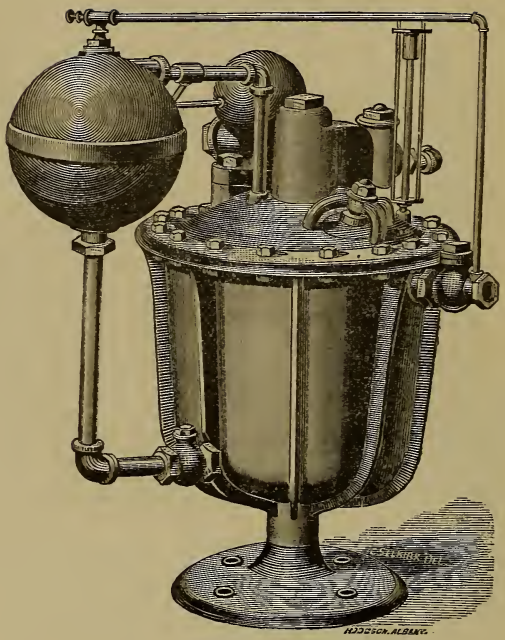


The Separator consists of a vertical cylinder having an internal central pipe extending from the top downward, about one-half its height, which forms the outlet pipe. The steam enters tangentially to the annular space between the inner and outer pipe at the side near the top of the apparatus. The speed of the incoming current produces centrifugal action, causing the steam to pass in a spiral line around the internal pipe down to its lower end where it abruptly changes its direction upward, passing through it and out at the top to the point where the steam is to be used. The entrained water thus separated by the centrifugal force is thrown to the outside of the downward current and falls into the collecting chamber below, from whence it can be blown off by hand or automatically drawn by a pump or trap and returned to the boiler without loss of temperature.

The importance of dry steam cannot be overrated for heating or power purposes. All steam contains entrained water, either from priming of boilers or condensation of pipes.

The Stratton Separator taking advantage of the rapidity of the steam current, produces centrifugal action, separates all the entrained water and delivers the steam dry, insuring greater efficiency for radiating surfaces, increased economy for steam engines, overcomes all danger from water in steam cylinders, and reduces wear and tear of pistons, rods and packing, and when placed between high and low pressure cylinders of compound engines increases their economy and efficiency.

Albany Steam Trap.



General View.

The operation of the trap in connection with the filter and boiler will be: The water from the purifier having on it the boiler pressure, will flow in through the inlet pipe and check valve, entering at first the annular chamber exterior to the bucket, after this annular space exterior to the bucket has been filled, the water will flow over its upper edge and commence to fill it and will also fill the tank through the

Cross Section through Syphon and Bucket.

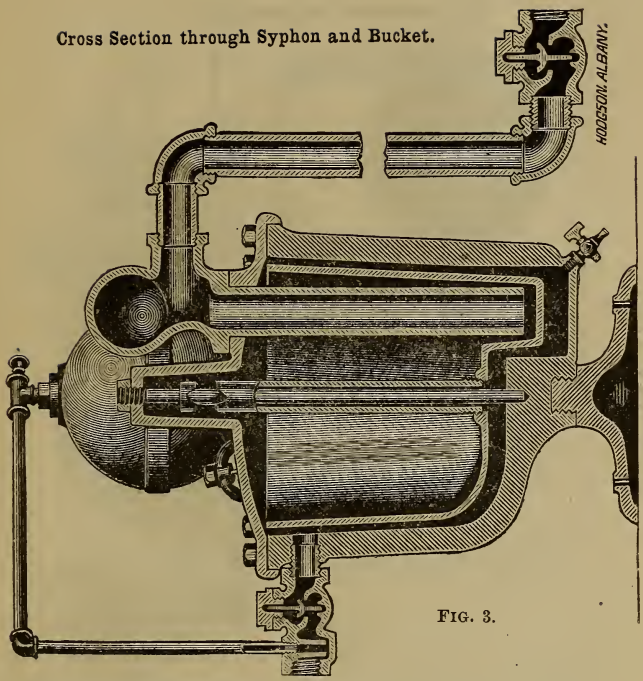
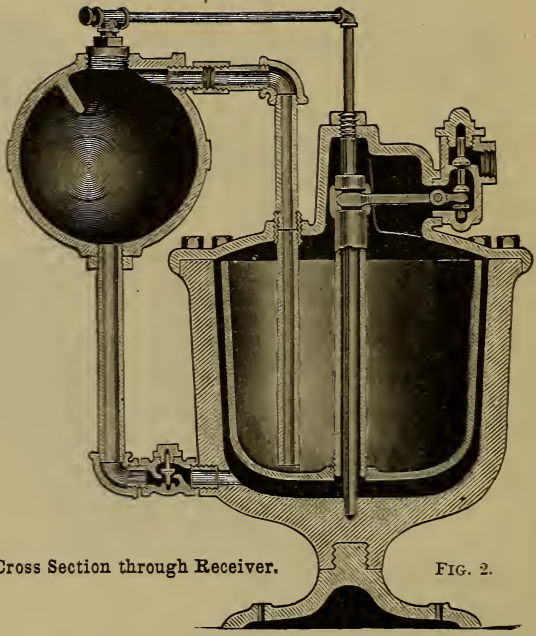


FIG. 3.

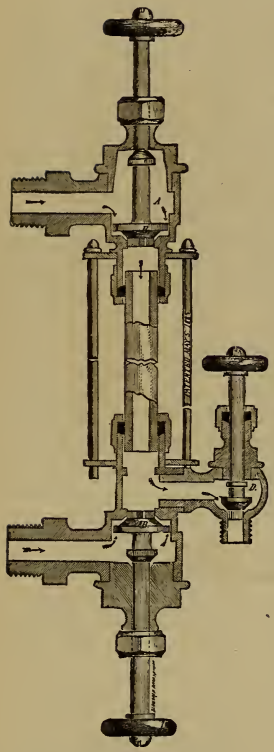
pipe leading from the bottom of the bucket. After sufficient water has entered the bucket to overcome its buoyancy, it will suddenly sink and at the same time open the equalizing valve, admitting steam from the boiler in a few seconds, the pressure having become equalized, the water contained in the bucket will begin to pass out through the syphon pipe into the boiler. After the bucket has been so far emptied as to uncover the lower end of the vertical pipe leading into the upper side of the tank,



Cross Section through Receiver. FIG. 2.

as shown in Fig. 2. steam will pass up through this pipe and equalize the pressure in the tank causing the containing water to flow into the annular space through the check valve shown on lower left side of Fig. 2. and thereby float the bucket upwards, closing the equalizing steam valve, and in a few seconds the pressure in the trap will become reduced from condensation. and again the water will be forced from the purifier into it as before described. and the trap will continue to repeat its operations. The trap should be set at least three feet above water line in boiler.

L. & N. Automatic Water Gauge.



The L. and N. Automatic Water Guage, as shown in this Cut, is simple in construction and effective in its workings. All the selfacting parts are under the control of the engineer or fireman, with or without pressure in the boiler. The principle is a cylinder and piston. The end of piston rod projecting through the stuffing box with handles attached. On the piston rod or (self-acting stems) are two valve seats; one in front of piston which closes and stops the flow of water and steam when a glass breaks, the other in the rear of piston, that keeps steam or water from escaping out through stuffing box when it is working under pressure. The stuffing box is only required to prevent steam or water escaping when a glass breaks as the rear valve then leaves its seat, the front valve closing. All the seats can be ground in while working under any pressure. Working on a boiler carrying, say, 60 pounds of steam, the self-acting valves are held open by about 15 pounds of pressure. When a glass breaks the whole force of steam acts on the piston and closes the valve.

The blow-off being placed between the inlet to boiler and end of glass tube, all sediment that may gather in the chamber can be thoroughly cleaned away. It is also the best indicator of amount of water in the boiler of

any appliance in use. It has large openings to boiler, giving a better circulation through the gauge.

In case a glass is broken by an accidental blow, or bursts through weakness or any other cause (*frequent occurrences*), **it will immediately close,** thereby preventing hot water and steam escaping from the boiler, scalding bystanders, or those in attendance, shutting down the engine, lost time by the stopping of machinery, and the necessity often of expensive repairs. After the engineer has left, and the factory or store closed for the night, a glass may break; when this occurs in establishments where goods are stored of such a nature as may be injured by steam, it can readily be seen that a preventative device of this kind is of incalculable value, for its reliability is certain, and can be depended on day or night, in the presence or absence of the person in charge.

What is Conduction of Heat?

It is the communication of heat from one body to another. In combustion in a furnace for evaporating water into steam, the heat of the fire penetrates through the boiler plates into the water, and drives its atoms apart, expands it; the water absorbs the heat from the fire, thus accomplishing the vaporisation. The latent heat of steam is usually reckoned at about 1.000 degrees. The boiling point of water being 212 degrees, is 180 degrees above the freezing point of water—the freezing point being 32 degrees; so that it requires 1.180 times as much heat to raise a pound of water into steam. It is found that the most perfect modern engines, when examined, do not convert more than about one tenth of the heat into power, the rest going off as waste steam.

In the "National Electric Furnace," an arrangement is presented to the public, wherein the waste steam is regenerated and utilized, (as already has been stated), by mixing it with the combustible gases, and returning it into the fuel, etc.

Atmospheric Pressure.—Pump.

How high will atmospheric pressure raise water in the bore of a pump?

It will raise water to an elevation of thirty feet above its level.

Why will it raise water to an elevation of thirty feet?

Because a column of water thirty feet high nearly balances the weight of a column of air of equal surface, extending to the whole height of the atmosphere. When, therefore, water is elevated to the height of thirty feet, the power of the pump is enfeebled, as the air and the water balance each other.

How is water raised to a greater elevation when it is required?

By mechanical contrivances, by which the water is forced to a greater elevation.

THE SUN.

What is the distance of the sun from the earth?

Ninety five millions of miles.

What is the constitution of the sun?

It is a spherical body, 1,384,472 times larger than the earth.

From what does the luminosity of the sun arise?

From a luminous atmosphere, or, as M. Arago named it, photosphere, which completely surrounds the body of the sun, and which is probably burning with great intensity.

Nearly all Solids become luminous at 800 degrees of heat F.

What is Water?

Water is the offspring of two gases, hydrogen and oxygen. If eight pounds of hydrogen and one pound of oxygen are mixed and ignited by a flame, they combine with a violent explosion and form nine pounds of limpid water. If this water is now sufficiently heated, e. g. by passing it slowly through a red hot tube, it quietly separates into its original gases—namely eight pounds of oxygen and one of hydrogen. Should we deal with these gases by volumes, instead of pounds, then three cubic feet of the combined gases, of which two are hydrogen and one oxygen, if mixed and exploded form water, but the water produced only occupies the two thousand six hundredth part of the space filled by the combined gases prior to the explosion.

Why is the Sea salty?

Because salt is a mineral which prevails largely in the earth, and which, being very soluble in water, is taken up by the ocean, lakes and rivers, also, even those that are considered fresh, hold in solution some degree of saline matters, which they contribute to the ocean.—As, in the evaporations from the sea, the salt remains in it, while the vapours fall as rain, and again wash the earth and carry some of its mineral properties to the ocean, the greater saltness of the sea, as compared with rivers, is accounted for. By some persons the opinion is entertained that the sea has been gradually getting saltier ever since the creation of the world. This, they say, arises from the evaporation of water free from salt, and the return of the water to the sea, taking with it salt from the land.

What is the Depth of the Sea?

The extreme depth has not, probably, been ascertained. But Sir James Ross took soundings about 900 miles west of St. Helena, whence he found the sea to be nearly six miles in depth. Now if we take the height of the highest mountain to be five miles, the distance from that extreme rise of the earth, to the known depth of the sea, will be no less than eleven miles.

What Proportion of the Earth's Surface is covered with Water?

There are about one hundred and forty seven millions of square miles of water, to forty-nine and a half millions of square miles of land.

How do the Waters of the Ocean become heated?

Chiefly by convection. Nearly all the heat which the sun sheds upon the ocean is born away from its surface by evaporation, or is radiated back into the atmosphere. But the ocean gathers its heat by convection from the earth. It girdles the shores of tropical lands where, being warmed to a high degree of temperature, it sets across the ocean from the Gulf of Mexico, and exercises an important influence upon the temperature of our latitude.

The Air, the Atmosphere we Breathe, is composed of four parts of nitrogen gas and one part of oxygen. For example, if we mix four gallons of nitrogen and one gallon of oxygen, we have five (5) gallons of air. It is the oxygen that supports life; the nitrogen is simply a diluent or spreader.

The Coal Industry.

The total product of bituminous coal in the United States for the census year closing June, 1880, amounted to 40,311,450 tons, of 2,000 pounds to the ton, divided among the States as follows: Alabama, 322,934 tons; Arkansas, 14,778; Georgia, 154,684; Illinois, 6,089,614; Indiana, 1,449,496; Iowa, 1,422,333; Kansas, 763,297; Kentucky, 935,857; Maryland, 2,227,844; Michigan, 100,800; Missouri, 543,900; Nebraska, 200; North Carolina, 700; Ohio, 3,922,853; Pennsylvania, 18,004,988; Tennessee, 494,891; Virginia, 40,520; West Virginia, 1,702,570. The number of laborers engaged in mining this vast amount of coal was 96,475, and the wages paid them were $30,707,059. There are only two states that produce anthracite coal, Pennsylvania and Rhode Island. The former produced 28,640,819 tons, and the latter 6,175 tons during the census year. The grand total of coal produced was 71,067,567 tons, and the grand total of hands employed was 170,585. The census bulletin makes comparison with the English production. The population of England is 25,000,000. The production of coal in that country in 1855 was 64,661,401 tons; in 1877, 136,179,968 tons, and in 1880, 146,818,152 tons. The number of collieries in England in 1880 was 3,380, and in the United States, 3,264. The production of coal in England, in an area about the size of Ohio, and with half the population of the United States, is double that of this country. England is supposed to be about up to its maximum, while this country is in the infancy of its coal development. There are hardly figures enough to compute its capacity in this respect, and its production for generations to come will depend upon

the demand. American manufacturing industries depend on coal, and in this respect there can be no failure. There are several States in which the deposits have been barely touched that are equal to the whole of England as coal States.

Chicago Journal of Commerce.

The Fuel Use of the City of London.

There are 8,000,000 of tons of coal, independent of other fuel materials, annually consumed in that great metropolis. In the area of London alone, no less than 200,000 tons of fuel are annually cast into the air in the form of smoke. And if we take into account the vast operation of nature in evaporation, fermentation, and putrefactive decomposition, we may be enabled to form a conception of the mighty part which that thin air, of which we think so little, plays in the grand alchemy of nature.

WHY DOES THE CHIMNEY SMOKE WHEN THE FIRE IS FIRST LIGHTED?—Because the air in the chimney is of the same temperature as that of the room, and therefore will not ascend.

WHY DOES THE SMOKING (INTO THE ROOM) CEASE, AFTER THE FIRE HAS BEEN LIGHTED A LITTLE WHILE? Because the air in the chimney being warmed by the fire beneath, becomes lighter and ascends rapidly.

WHY DOES A LONG CHIMNEY CREATE A GREATER DRAUGHT THAN A SHORT ONE?—Because the short chimney contains less air than the long one; there is, consequently, less difference of weight between the warm air of the short chimney and the external air; it therefore has not so great an ascensive power.

Useful Notes on Specific Heat for Engineers and Firemen.

The specific heat of any substance is the quantity of heat expressed in *thermal units* which must be transferred to a pound of the substance to raise its temperature 1° Fahr.

A thermal unit is the quantity of heat required to raise the temperature of a pound of water from 39.1° to 40.1° Fahr.

The specific heat of different bodies varies greatly; it is therefore necessary to select some convenient substance and make its specific heat a standard by which that of other bodies may be compared. *Water* is the most convenient substance for this purpose, therefore it has been selected for such a standard, and the amount of heat required to raise the temperature of a pound of it 1° Fahr., has been fixed upon as the standard by which all quantities of heat shall be compared.

The reason why the temperature from 39.1° to 40.1° Fahr. is chosen is because 39.1° is the temperature of greatest density of water, and its specific heat, as well as that of all other substances, is different at different temperatures. Thus, it requires about one-twentieth more heat to raise the temperature of a pound of water from 211° to 212° than it does to raise it from 39.1° 40.1°.

Fuels.—All those bodies are called fuels, which are capable of combining with the oxygen of the air. Such a combination is combustion, and restores the heat and light that had originally been taken from the sun.

The highest Heat of a common wood fire is estimated at 1140° Fahr.

Open Heaters, Grease in Boilers.

Is there any objection where the modern preparations of petroleum are used for Cylinder oils?—The objection is not as great as when animal oils are used. Still, we find more or less difficulty. The deposit which accumulates is of a tenacious, waxy character, and is more frequently found adhering to the sides of the boiler near the water line and around the upper tubes. We are a little troubled to account for this, but are of the opinion that it is the paraffine in the oil. It should be borne in mind that a large proportion of the oil used in the cylinder is thrown out in the exhaust. We will suppose that one pint of oil is used in a cylinder each day. If the exhaust is returned to the boiler there will have been carried into it in one month not much less than three gallons. If the water is liable to be muddy or carries any considerable quantity of vegetable matter, the oil will combine with it more or less, and certainly give trouble. Therefore, from a wide experience we advise that the exhaust be utilized to heat the feed water, without bringing it in contact with it, which can not be done unless a pipe or coil heater is used. Crude petroleum is very effective in removing hard scale. But it should be put into the boiler when it is comparatively cool, after blowing down and cleaning out the boiler. The crude petroleum may be put in when the boiler is being filled; it will rise to the surface of the water, and as the water rises in the process of filling, the sides of the boiler will be washed by the rising oil on the surface. We have been able to remove hard scale in this way which could not be removed by any other process. Crude petroleum is volatile, and the amount of residuum which would result from the quantity used

in a boiler for such purposes would be so small as to be harmless. We would not, however, advise the indiscriminate use of crude petroleum. If the water carries vegetable matter, or is liable to be muddy, other purgers will be better. But for a hard lime scale we have found crude petroleum very effective. It will be observed that the conditions under which the oil is used in this case are different from those where it is introduced in the exhaust from the engine. In the latter case it is introduced into the water, which is at a high temperature, and may have more or less impurity or scum on the surface; the oil readily combines with this, causing the difficulties mentioned above. While in the former case the oil is introduced cold into cold water, it washes, or "varnishes" the sides of the scale-covered boiler, penetrates it, works its way between the scale and the iron of the boiler, and detaches it. Those who have used petroleum to aid in removing a nut from a rusted bolt will understand its operation. It eats out or dissolves the rust or oxide without injuring the iron. So with hard scale, it works down between the iron and the scale, eats out or lubricates the film of oxide, and detaches it.

The Locomotive.

WHY IS IT DANGEROUS TO SIT NEAR A FIRE DURING AN ELECTRIC STORM?—Because the chimney, being a tall object, and smoke a good conductor, would probably attract the Electricity, and convey it to the body of a person sitting near the fire.

THE SPEED OF AN ELECTRIC SPARK travelling over a copper wire, has been ascertained by Wheatstom to be 288,000 mi. in a second.

Earthquakes.

Earthquakes arise from undulations, heavings, and splittings in the earth, caused by the expansion of substances under the effects of terrestrial fires. Large masses of rock are sometimes hurled from mountains, or forced to the surface, from beneath the bowels of the earth. One theory explanatory of earthquakes is, that our globe, and all other planetary bodies, were originally in a state of fire, and have since been gradually cooling; that there yet exist within the bowels of the earth the remains of its former incandescent state; that water sometimes finds its way to the heated mass within; and that this generates steam and gases which, in escaping, rupture and disturb the earth. Another theory is, that the earth contains chemical elements; which, under certain circumstances, act upon each other and produce fire; or, under the action of water, explode, melt, and fuse—by the intensity of heat—the parts of the earth around them. The effects of earthquakes, when they are severe, in populous districts, are very terrible. In cities, churches and buildings of every description are thrown down; thousands of people are crushed to death; fire seizes upon the ruins, and, in some instances, whole cities are buried.

In the year 543, a great earthquake was felt throughout the known world; in 742, more than 500 towns were destroyed in Syria, Palestine, and Asia; and the loss of lives was beyond all calculation; in 1137, 15,000 people perished in the ruins caused by an earthquake in Catania, in Sicily; 40,000 people perished by a similar cause at Naples, in 1456; in 1531, 1500 houses were thrown down at Lisbon, and 30,000 people perished; in 1693, another oc-

curred in Sicily, and destroyed Catania and its 18,000 inhabitants. Altogether, more than 100,000 lives were lost. In 1731, another occurred in China, when 100,000 people were swallowed up at Pekin; at the great earthquake in Lisbon 1755, in about eight minutes, 50,000 inhabitants were swallowed up, and the principal parts of the City buried. In 1743, the town of Guatemala, in Mexico—with all its riches, and 8000 families—was swallowed up, the spot were it was buried being now a complete desert.—*Bibli. Rea. Why.*

CONCLUSION.

Our task has now come to its end. The selections and teachings herein set forth, are such as we thought worth knowing, and we sincerely hope they will enable those, who are entirely unacquainted with the science of combustion, to understand the same. They are not new, as they come before our eyes every day. Many persons may not have the means of knowing them, except through some such effort as this. Many of the dear readers also may not be acquainted or familiar with the science of chemistry and with chemical terms. Such we would friendly advise to peruse the material offered in this little volume, to read over and over again, and we are surely convinced that a more perfect understanding of the science of combustion will be the result.

The book also contains, as the reader will have perceived, an assortment of miscellaneous valuable and useful information, comprising what we thought mostly new and interesting. We have tried to avoid giving a great number of tables and calculations,

since we believe that the majority of readers care very little for them, and have, therefore, given only such as we thought to be of special interest. We have collected them with much care and expense for the benefit of the reader, certainly not for that of the writer, who is quite content with the thought of having tried to benefit others. The reader may as a return favor, if he finds it valuable enough, let his friends know of this little volume's being in existence, and so help to bring the information therein contained to others. —In compiling this little volume, the writer was led by a maxim well worthy of imitation.—A worthy quaker wrote thus: "I expect to pass through this world but once. If, therefore, there be any kindness I can do to any fellow being, let me do it now, for I will not pass this way again." Were all to act thus, how many would be made happy!

END.

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